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U.S. ARMY ELECTRONICS MATERIEL AGENCY
CONTRACT NO. DA-36-039-SC-86726
QUARTERLY REPORT FOR THE PERIOD
JULY 31, 1962 TO OCTOBER 30, 1962

PRODUCTION ENGINEERING MEASURE

2N914 AND 2N995

QUARTERLY REPORT

FOR THE PERIOD

JULY 31, 1962 TO OCTOBER 30, 1962

OBJECT:

IMPROVE PRODUCTION TECHNIQUES TO INCREASE THE RELIABILITY OF SILICON PLANAR EPITAXIAL TRANSISTORS 2N914 AND 2N995

CONTRACT NO. DA-36-039-SC-86726
ORDER NO. 19048-PP-62-81-81

PLACED BY

U.S. ARMY ELECTRONICS MATERIEL AGENCY

PHILADELPHIA, PENNSYLVANIA

PREPARED BY: D. M. KOBRIN

APPROVED BY: P. W. HILL

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SECTION I
PURPOSE

Contract No. DA-36-039-SC-86726 is a Production Engineering Measure for improvement of production techniques to increase the reliability of 2N914 and 2N995 transistors. Processes to be improved include.

a. Lead Attach

b. Preparation of Substrate for Epitaxial Growth

c. Header Plating

d. Particle Elimination

e. Die Attach

SECTION II
ABSTRACT

This second quarterly report presents a detailed narrative of the portion of the work accomplished in August, September, and October of 1962, in each task under PEM contract No. DA-36-039-SC-86726. Data, sketches, and reports relative to the second quarter's work are appended to the discussion of each task.

SECTION III

NARRATIVE AND DATA, CONCLUSIONS, FUTURE PROGRAM

Each of the nine subsections which follow has been authored by the engineer in charge of the task described. Because the projects are relatively autonomous the narrative, conclusions, data, and plans for each project have been consolidated in these subsections, rather than presented in separate sections of the report.

A cover sheet precedes each subsection, identifying the material contained within it.

SECTION III

TASK 1A - CHANGE IN METAL SYSTEM

CONTENTS

SECTION III

TASK 1A - CHANGE IN METAL SYSTEM

W. J. Warren

PURPOSE

The capillary bonds between gold wire and aluminum patterns on small geometry devices sometimes fail at the gold-aluminum interface during life testing at temperatures greater than 200°C. This is due to diffusion of gold into aluminum at elevated temperatures, forming a third composition $AuAl_2$. The large scale atomic diffusion causes voids to form at the bonded interface, and this causes mechanical bond failure.

The purpose of this project is to determine the feasibility of developing alternate systems to the gold-wire-aluminum-pattern system presently used. It is desired that any new systems should maintain the ball bonding thermal compression technique if possible.

It was initially decided that metallized layers of platinum and palladium should be investigated. It was decided that silver should be investigated also since it had desirable properties such as nobility, the formation of no intermetallics with gold, and low resistivity. Also, it was reported by the Research and Development department at Fairchild that silver could be easily evaporated and that the silver pattern did not affect the electrical parameters of transistors.

BACKGROUND

It was proved in the last period that palladium metallized devices could be made with satisfactory electrical parameters. However, problems were found to exist in lead bonding gold wire to the metallized dice.

PROGRESS DURING THIS PERIOD

As stated in the last report, ninety-two palladium metallized dice were lead bonded after die attach. However, the yield for the lead bonding operation was very low and it was therefore resolved to attempt to lead bond

before die attach. This allowed temperatures higher than the AuSi eutectic temperature (370°C) to be used to form the Au-Pd capillary bonds.

Dice fabricated by the process described in the last report were held in the hard chromium-plated brass jig described in that report. Lead bonding to the dice was attempted under different load, time and temperature conditions. At 400°C, weak bonds were obtained between the palladium and the gold. However lead bonding before die attach was found to present two serious problems:

1) It was extremely difficult to remove the lead-bonded dice from the holding jig and then perform the die attach operation without mechanically dislodging the bonded leads;

2) The metal mask often did not exactly cover the emitter and base regions, leaving some silicon surface bordering the palladium. When the gold ball overlapped the palladium and touched the silicon then the ball dissolved as molten gold-silicon eutectic at temperatures greater than 370°C.

These disadvantages caused the abandonment of further attempts at lead bonding before die attach. It was resolved that further tests should involve conventional low temperature (345°C ± 10°) lead bonding after die attach.

Several different approaches were tried using different metallized layers and different wires: (a) evaporating a layer of gold over the palladium to test the properties of a gold wire to gold surface capillary bond; (b) using a silver metallized layer with either gold, palladium, or silver wire; (c) using palladium as a metallized layer with different metallizing processes than those previously tried.

Further details of these approaches are given below:

1. Metallized layer: Gold over palladium
   Wire: Gold

Different amounts of palladium and gold and different alloying schedules were tried as shown in exhibit 1 at the end of this report. Bo nding tests to the specimens showed the following results: (a) At bonding temperatures greater

else causing such bad undercutting at the edges of the emitter and base rings that the adhesion between the silver and silicon was seriously weakened. One method of KPR removal which was used was to burn off the KPR at high temperature, allowing further alloying between the silver and the silicon to occur simultaneously. Another satisfactory method was to dissolve away the KPR by soaking the wafers in acetone.

(f) Bonding tests were carried out on dice after the die attach operation where this was possible. However, occasionally preliminary bonding tests were carried out at an earlier step, for instance to the wafer after alloying and before etching. This was done if it was thought possible that the etching operation might ruin the metal pattern. In some cases only approximate estimates were made for the frequency of bonding. However, records were kept for small bonding samples showing the relative numbers of successful and unsuccessful bonds. It was also noted whether lack of success was due to lack of sticking of the gold ball to the silver caused by unfavorable silver surface condition, or due to the silver layer being torn away from the silicon owing to poor silver silicon alloying.

(g) Several methods of mechanically evaluating the bonds were tried:

1. Standard in-plant centrifuge tests at 40,000 g's for two minutes were carried out on canned devices. The cans were removed after the test and visual examination showed whether the bonds had failed or not, and where failures had occurred (i.e. under the ball or under the metal).

2. The wires were pulled with tweezers until bond failure occurred. This test was used on bonds to wafers and to dice mounted on headers. It was observed whether failure occurred in the span of the wire, or under the ball, or under the metal pattern. Ideally, all failures would occur in the span of the wire; this happened when pulling forth bonded aluminized devices used as a standard reference.

3. The bonded wires were attached to a dynamometer and pulled until failure. As well as observing where bond failure occurred, the dynamometer reading, showing the bond breaking strength in grams, was recorded. The pull strengths could be compared with those obtained on pulling .002" diameter gold wire bonded to aluminized 2N696 units:

20 bonded emitters...wires broke in span...mean pull strength 20.3 grms.

20 bonded bases ...wires broke in span....mean pull strength 21.4 grms.

(h) One simple test was used to evaluate the effect of heat on the bonds. Bonded units were aged in an oven at 300°C in a nitrogen atmosphers. They were removed from the oven and inspected for bond failure from time to time.

COMMENTS ON THE TESTS PERFORMED.

Runs 1, 2 and 3 (in exhibit 2 at the end of this report) were all ruined at the KPR removal stage because the chromic acid attacked the silver metal. However, some bonds were made to wafers of runs 2 and 3 before etching. The results of pulling bonds to run 3 oxidized wafers showed that the aluminum under the silver adhered well to silicon dioxide after the 580°C, 3-minute alloying treatment.

Some lifting of the silver pattern occurred in run 4. The reason for this was that the wafers were etched before the alloying treatment coincidental with KPR removal; hence the etchant seeped in at the silver-silicon interface and attacked the silver. The lifting of the metal caused many of the pulled bonds to fail beneath the metal.

Run 5 was unetched in order to test the bonding properties of unetched silver. The pull tests showed that the bonds made were of considerable strength, although the centrifuge test caused some failures below the silver pattern. This suggested that the total alloying of 830°C for 6 minutes was insufficient to bond the silver to the silicon. The results of high tempera-

ture aging showed that bond failure began to occur after 40 hours at 300°C in nitrogen. On inspecting the failures due to aging it appeared that the silver had diffused into the gold ball leaving a void beneath the gold ball.

Runs 6 and 7 were not successful owing to the high 830°C alloying temperature used. The aluminum-silicon eutectic melted at 580°C and hence most of the aluminum fused and flowed at 830°C.

A long alloying time was used for run 8 since 830°C for 6 minutes was shown to be insufficient in run 5. Bonding of gold wire to the silver was usually successful, although some metal lifting showed that alloying was not wholly successful, and occasional non-adherence of the gold to the silver was perhaps due to oxidation of the silver surface by the ferric nitrate. Aging some bonds made with gold wire supported previous evidence that failure began after 40 hours at 300°C.

Palladium wire did not capillary bond to run 8 units.

Some success was obtained in capillary bonding silver wire to run 8 units.

Conclusions.

The failure of capillary-bonded gold wire during the 300°C life test after 40 hours was a serious disadvantage to the use of silver metallization. The substitution of silver wire for gold wire showed some promise, even though the silver wire fused to form tear-drop balls which were hard to work with instead of the easily bondable round balls that gold formed. Palladium wire did not thermo-compression bond to silver patterns.

A satisfactory alloying schedule has not yet been found in the present tests, but longer times than those tried should be effective.

3. Metallized layer: Paladium
   wire: Gold

Processes used for metallizing, bonding, and evaluating bond strength are described in exhibit 3 at the end of this report.

Metallizing and alloy methods were the same for palladium as for silver. However, aqua regia at room temperature was used as an etchant for the

palladium. Owing to the poor adherence of Pd to silicon dioxide, the use of Kodak Photo Resist or Kodak Metal Etch Resist masking prior to etching was sometimes unnecessary; a very short aqua regia etch was often sufficient to float the unwanted palladium off the oxide without seriously affecting the metal over the silicon. However, metal masking was necessary for small geometry 2N914 and 2N995 devices, since it was otherwise found to be very hard to remove the metal over the oxide between emitter and base. After etching masked small geometry units, the KPR or KMER was removed by 80°C chromic acid or by acetone.

Methods of bonding and evaluating bond strength were the same as those previously described for silver.

As can be seen from exhibit 3, many different metal evaporations and alloy schedules were tried, in order to obtain a process which would give a metal layer with a clean, pure palladium surface. Bonding tests to a thin sheet of pure palladium showed that gold wire would capillary bond to it perfectly at normal bonding temperatures (345°C); when the bonds were pulled, failure occurred in the span of the wire every time showing that gold-palladium bonds were of a strength comparable to gold-aluminum bonds.

Many complex materials, of differing colors and textures, appeared in evaporated palladium in the course of the processes attempted. It was difficult to deduce in every case the exact nature of the palladium compound produced; however, these compounds usually hindered either the palladium-silicon alloying or palladium- gold bonding to some degree.

A discussion of some of the compounds seen:

A pink oxide appeared on palladium at 300°C or higher in air. The oxide appeared when wafers or dice were left on the heater block for more than a minute during the lead bonding operation. However, the oxide did not seem to impair the bonding properties between the gold ball and the palladium.

A thick black deposit appeared over the emitter dot and base rings of runs #7, 8, 9, 10. The deposit was first observed after the evaporation and before the alloying step, and this was only visible in palladium over silicon and not in palladium over oxide. Scratching the black deposit revealed that it extended throughout the metallized layer down to the silicon substrate. It was formed in the four runs in which the wafers were heated to about 600°C on tantalum strips during the evaporation. Since the evaporation took place in an evacuated bell jar, it does not seem likely that the deposit was an oxide. It is thought that the deposit was formed by rapid interdiffusion of silicon and palladium during the evaporation, and is an intimate mixture of silicon and palladium. This would explain why it occurred throughout the metallized layer over silicon, did not occur over silicon dioxide, and did not depend on the presence of oxygen. The black meterial was not encountered again after heating of the wafers during evaporation was discontinued.

A brown material was observed over the silicon only, not over the silicon dioxide, in runs #17, 25, 28. It appeared after the alloying treatment and existed as a thin layer over the white palladium beneath. The layer structure over palladium suggests strongly that the brown deposit was an oxide. This was supported by the fact that it was only formed during long alloying treatments sf 20 minutes or more, since an appreciable amount of oxygen might be carried into the alloying furnace with the inert gas ambient over these prolonged times. However, since the oxide was only formed over palladium over the silicon and not palladium over silicon dioxide, it was probably a complex oxide of silicon and palladium.

Many of the problems encountered using palladium metallization were due to palladium-silicon interdiffusion and to oxide formation. Two approaches were tried to overcome these disadvantages - 1) double evaporation and 2) short alloying times.

The principle of double evaporation was that a layer of pure palladium be evaporated over the alloyed, and possibly impure, first palladium layer. Bonding to the pure second layer of palladium would then be easy. Problems were encountered in obtaining satisfactory bonding between the first and the second palladium layers. For instance, in run #27, bond failure always occurred at the interface between the first and second metal layers. Therefore, in run #29, a second alloying step was added after the second evaporation. Thirty 2N696 units were lead bonded and lead welded without loss, even though some bonds pulled to destruction still failed between the first and second metal layers. Run #30 used the same metallizing and alloying steps as run #29, but on small geometry 2N995 PNP units. Lead bonding problems were encountered in run #30 since it was not found possible to remove all of the KMER from the emitter dots and base rings after etching off the unwanted metal. About twenty lead bonded and welded units were nevertheless produced. Double evaporations with double alloying were tried in runs #31, 32, 33 on small geometry, NPN, devices. It was found impossible to remove the KMER from run #32, or the PKR from run #33, after etching; this led to poor lead bonding results. Lifting of the metal between the first and second metal layers occurred when bonds to run #31 wafers were pulled to failure.

The KMER or KPR removal problem was one that often occurred during the small geometry runs. KMER was first used as a masking material, and KPR was later tried in the hope that it would give better results; however, the same problem was encountered with KPR as with KMER. Long etching times of approximately 5-10 minutes in 80°C chromic acid were needed to remove the masking material, and it was found that the chromic acid attacked and removed the palladium simultaneously. It was therefore decided to use acetone for removal of the maskant. The masked wafers were alternately ultrasonically cleaned in an acetone bath and lightly swabbed with acetone-soaked cotton buds, until the KPR or KMER was removed. This method was successfully used for run #39.

Since it was found to be difficult to get perfect adhesion between the first and second metal layers using a double evaporation, another approach to the metallization problem was tried; this was the second approach referred to previously. Short alloy times were used since this allowed less time for oxidation or for palladium-silicon interdiffusion to occur at the alloying temperatures. In runs #34-41, greater amounts of palladium were evaporated since it was believed that this would make a longer path for passage of silicon to the palladium surface; therefore contamination of the palladium surface by silicon would be less likely.

Runs #34, 35, 36 were of considerable interest in showing evidence of diffusion of palladium into silicon. In these runs, 3000 mg of palladium were evaporated from the tungsten filament. In run #34 wafers were alloyed for half a minute at 725°C. A clean, thick palladium surface was produced (see exhibit 4) to which forty bonds, all breaking in wire span on pulling, were made. In run #35 alloying was for three-quarters of a minute at 725°C and some greyish palladium-silicon appeared in some emitter and base areas. Run #36 was alloyed for one minute and more palladium-silicon areas were visible in emitters and bases (see exhibit 4). One interesting fact was that the run #6 photo showed a downward step from the palladium to the dark palladium silicon area. This very strongly suggested that the rapid diffusion of palladium into silicon was a dominant mechanism of palladium-silicon mixing.

A table was drawn up showing those alloying treatments used which were the longest to allow a pure palladium surface, and the shortest to show a palladium-silicon mixture. This table may be found in exhibit 5 at the end of this report. The table shows the critical alloying treatments for different amounts of palladium evaporated. Since there were three variables - alloy time, alloy temperature, and mg palladium evaporated -and only a limited amount of information, it was not considered practicable to present the information in graphical form. However, definite trends may be seen from the results.

Longer alloying times at higher temperatures were needed to produce the palladium-silicon mixtures for wafers with a heavier deposition of palladium. This is the result which would be expected for interdiffusion of palladium and silicon, and justified the decision to evaporate thick layers of palladium.

It was found better to try alloying at as low a temperature as possible, and for a long time, rather than alloying for very short times at higher temperatures. The latter approach is not preferable since it was found inconvenient to anneal for times within very critical limits. Annealing schedules of 300°C for 2 hours in nitrogen were used on runs #39 and #41, and this was found to be very promising. Bonds were easily made to wafers after alloying, and nearly all pulled bonds broke in the span of the wire. However, trouble was encountered in lead bonding satisfactorily after the die attach step in run #39. Bonds could be made reproducibly, but about 50% of them were not strong enough to survive the lead weld step. Even so, fifty completed devices from this run have been produced so far with good electrical characteristics. The deterioration in bonding properties after masking and etching was probably due to some KPR being left on the emitter and base areas.

Tests were carried out to find the effects of high temperature aging on bonded palladium metallized units. Fourteen bonded units of run #7 were aged at 300°C in N_2 for 300 hours. Visual examination showed that no failures had occurred after this time.

Conclusions:

Palladium metallization can be used to give units with good electrical properties, which will survive aging at 300°C in N_2 for 300 hours without bond failure..

The thickness of the palladium layer and the alloying schedule are critical since interdiffusion of palladium and silicon, which in an advanced stage will ruin bonding properties, occurs rapidly at high temperatures.

The removal of maskant, after etching away unwanted metal is still a problem.

Silver and palladium both appear to be promising as replacements for aluminum.

However, silver patterns cannot be used with gold wire since bond failure occurs after forty hours in N at 300°C. A replacement must be found for the gold lead wire.

Palladium can be used to metallize silicon transistors without any apparent degradation of the transistor parameters. However, the metallizing and alloying process is quite critical. Since gross palladium-silicon interdiffusion will deteriorate the lead bonding properties of the palladium surface.

PROGRAM FOR NEXT INTERVAL

Further work is planned to find a metallizing and alloying process for palladium which will give reproducible good results. Life and environmental tests will be performed on 250 devices produced by this process.

Attempts will be made to find a replacement for gold wire to be used with silver patterns.

TASK 1A - EXHIBIT 1

PROCESSES USED FOR GOLD OVER PALLADIUM METALLIZATION

Run No.	mg Pd Alloy 630°C 4-1/2M	1st Evaporation			2nd Evaporation		
		mg Au	Alloy Time (m)	Alloy Temp °C	mg Au	Alloy Time (m)	Alloy Temp °C
1	700	200	4-1/2	400	300	None	
2	700	200	4-1/2	400	300	2	400
3	700	250	4-1/2	400	250	None	
4	350	100	4-1/2	400	150	None	
4	350	100	4-1/2	400	150	2	400

TASK 1A - EXHIBIT 2

PROCESSES AND TESTS FOR SILVER (± ALUMINUM) METALLIZATION

Run #	Substrate	Evap Metal and Wt	Alloy Sched Temp °C	Alloy Sched Time (Mins)	Alloy Sched Ambient	Etchant (if any)	Etch Time	Method of KPR Removal	Etch Results	Bonding Conditions: Wire Used For Bonding	Bonding Conditions: Step Where Bonding Tests Made	Bonding Conditions: Time	Bonding Conditions: Temp °C	Approx % Bonds
1	N Type Wafer	Ag 700 mg	830	3	Forming gas	20% Ferric Nitrate	6 Mins	Chromic Acid	Ag was dissolved in Chromic Acid					
2	N Type Wafer	Al 20 mg + Ag 700 mg	580	3	N_2	20% Ferric Nitrate	6 Mins	Chromic Acid	Ag undercut by Chromic Acid	.002 " Au	Wafer After Alloy	5	345	80
3	Oxidised Wafer	Al 20 mg + Ag 700 mg	580	3	N_2	20% Ferric Nitrate	6 Mins	Chromic Acid	Ag undercut by Chromic Acid	.002 " Au	Wafer After Alloy	5	345	80
4	4200 Wafers	600 mg Ag	See KPR Removal			20% Ferric Nitrate	1m 10s	830°C,3m in forming gas	Some lifting	.002 "	After die Attach	5	345	45
5	4200 Wafers	600 mg Ag	830	3	Form gas	None	-	830°C,3m in forming gas	-	.002 " Au	After die Attach Unetched	5	345	100
6	4200 Wafers	20 mg Al + 600 mg Ag	See KPR Removal			20% Ferric Nitrate	30 s	830°C,3m in forming gas	Metal discolored Brown	.002 " Au	Wafer After Etch	5	345	10
7	4200 Wafers	20 mg Al + 600 mg Ag	830	3	Form gas	35% Ferric Nitrate	7 m	830°C,3m in F.G.	Metal discolored Brown	.002 " Au	Wafer After Etch	5	345	20
8	4200	600 mg Ag	830 + 810	6 + 20	Form gas	20% Ferric Nitrate	6 m	Acetone	Good	.002 " Pd	After Die	5	345	0
										.002 " Au	Attach	5	345	80
										.001 " Ag		5	345	

TASK 1A - EXHIBIT 2 (Continued)

PROCESSES AND TESTS FOR SILVER (± ALUMINUM) METALLIZATION (Continued)

Run #	Substrate	Evap Metal and Wt	Bonding Results: # Bonds Attempted E	B	Bonds Made E	B	Ball Won't Stick E	B	Metal Lifts E	B	Pull Tests: Sample Size E	B	Failed in Span: Number E	B	Mean Pull (g) E	B	Below Ball: Number E	B	Mean Pull (g) E	B	Below Metal: Number E	B	Mean Pull (g) E	B
1	N Type Wafer	Ag 700 mg																						
2	N Type Wafer	Al 20 mg + Ag 700 mg																						
3	Oxidised Wafer	Al 20 mg + Ag 700 mg									5	4	4	4			1							
4	4200 Wafers	600 mg Ag									7	10		2		23.0					7	8	6.4	5.3
5	4200 Wafers	600 mg Ag									19	19	19	12	20.1	20.8						7		15.8
6	4200 Wafers	20 mg Al + 600 mg Ag																						
7	4200 Wafers	20 mg Al + 600 mg Ag																						
8	4200 Wafers	600 mg Ag	10	10	0	0	5	9	5	1														
			15	15	8	15	0	0	7	0														
			14	11	7	9	1	2	6	0														

TASK 1A - EXHIBIT 2 (Continued)

PROCESSES AND TESTS FOR SILVER (± ALUMINUM) METALLIZATION (Continued)

Run #	Substrate	Evap Metal and Wt	Ageing at 300°C in N_2							Centrifuge							
			Sample Size		Age Time (Hrs)	Failed Below Ball		Below Metal		Sample Size		Survived		Failed Below Ball		Below Metal	
			E	B	Total	E	B	E	B	E	B	E	B	E	B	E	B
1	N Type Wafer	Ag 700 mg															
2	N Type Wafer	Al 20 mg + Ag 700 mg															
3	Oxidised Wafer	Al 20 mg + Ag 700 mg															
4	4200 Wafers	600 mg Ag															
5	4200 Wafers	600 mg Ag	10	10	41 65			1 8	2 3	20	20	19	15			1	5
6	4200 Wafers	20 mg Al + 600 mg Ag															
7	4200 Wafers	20 mg Al + 600 mg Ag															
8	4200 Wafers (.002" Au Bonding wire only)	600 mg Ag	8	15	19 43 71 192	0	0	0 3 3 5	0 2 7 15								

PROCESSES AND TESTS USED FOR PALLADIUM METALLIZING

RUN #	SUBSTRATE	METAL EVAP AND WT	ALLOY TEMP °C	SCHEDULE TIME (MIN)	SCHEDULE AMBIENT	ETCHANT	ETCH TIME	METHOD OF KPR OR KMER REMOVAL	ETCH RESULTS	BOND CONDITIONS STEP WHERE TEST MADE	BOND CONDITIONS WIRE USED FOR BONDING	BOND CONDITIONS TIME (SECS)	BOND CONDITIONS TEMP °C	APPROX % BONDS	# BONDS ATTEMPTED E	# BONDS ATTEMPTED B	# BONDS MADE E	# BONDS MADE B	BALL WON'T STICK E	BALL WON'T STICK B	PULL TESTS METAL LIFTS E	PULL TESTS METAL LIFTS B	PULL TESTS SAMPLE SIZE #UNITS E	PULL TESTS SAMPLE SIZE #UNITS B	PULL TESTS FAILED IN SPAN NUMBER E	PULL TESTS FAILED IN SPAN NUMBER B	PULL TESTS MEAN PULL (g) E	PULL TESTS MEAN PULL (g) B
1	N TYPE WAFERS	N				NONE				WAFER AFTER ALLOY	.002" Pd	5	345	100													
2	4200 WAFERS	700 mg Pd	700	10	FORMING GAS	NONE				WAFER AFTER ALLOY	.002" Au	5	370	~80									17	17	11	12	
3	OXIDE WAFERS	700 mg Pd	700	20	FORM GAS	NONE				WAFER AFTER ALLOY	.002" Au	5	345										8	9	8	8	
4	OXIDE WAFERS	350 mg Pd	700	20	FORM GAS	NONE				WAFER AFTER ALLOY	.002" Au	5	345										9	9	6	6	
5	N TYPE WAFERS	700 mg Pd	700	10	FORM GAS	AQUA REGIA	2m		OVER-ETCHED METAL REMOVED	WAFER AFTER ALLOY	.002" Au	5	345	80									10	10	4	3	
6	N TYPE WAFERS	700 mg Pd	700	20	FORM GAS	AQUA REGIA	2m		OVER-ETCHED METAL REMOVED	WAFER AFTER ALLOY	.002" Au	5	345	80									3	3	3	2	
7	4200 WAFERS (PREHEAT)	700 mg Pd	720 + 700	3 + 20	FORM GAS	AQUA REGIA	20S	CHROMIC ACID	SATIS	AFTER DIE ATTACH	.002" Au	12	345	~95									14	14	13	11	21.8	21.0
8	4200 WAFERS (PREHEAT)	700 mg Pd	700	20	FORM GAS	AQUA REGIA	20S	CHROMIC ACID	SATIS	AFTER DIE ATTACH	.002" Au	12	345	50														
9	4200 WAFERS (PREHEAT)	700 mg Pd	720 + 700	3 20	N_2	NONE				WAFER AFTER ALLOY	.002" Au	5	345	70									10	10				
10	4200 WAFERS (PREHEAT)	700 mg Pd	700	20	N_2	NONE																						
11	4200 WAFERS	700 mg Pd	720 + 700	3 20	N_2	NONE				WAFER AFTER ALLOY	.002" Au	5	345	0														
12	4200 WAFERS	700 mg Pd	700	20	N_2	NONE																						
13	4200 WAFERS	1000 mg Pd	450	20	N_2	NONE				WAFER AFTER ALLOY	.002" Au	5	345		17	17	8	14			9	3						
14			450	3	N_2	NONE						5	345		8	8	7	5			1	3						
15			250	15	N_2	NONE						5	345		4	4	4	3			1	0						
16	4200 WAFERS	1000 mg Pd THEN 1000 mg	480	3	N_2	NONE				WAFER AFTER	.002" Au	10	345		10	10	10	10					10	10	7			

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PROCESSES AND TESTS USED FOR PALLADIUM METALLIZING

Below Ball Number		Below Ball Mean Pull(g)		Below Metal Number		Below Metal Mean Pull(g)		Ageing 300°C in N_2 Sample Size		Age Time (hr)	Failed Below Ball		Failed Below Metal		Centrifuge 40,000 g's Sample Size		Survived		Failed Below Ball		Failed Below Metal		Run #
E	B	E	B	E	B	E	B	E	B		E	B	E	B	E	B	E	B	E	B	E	B	
								16	16	16			8	8	16	16	16	16					1
				6	5																		2
					1																		3
				3	3																		4
6	7																						5
	1																						6
1	3	0.5	14.7					14	14	300	0	0	0	0									7
								2	2	92	0	0	0	0									8
10	10																						9
																							10
																							11
																							12
																							13
				1	3																		14

PROCESSES AND TESTS USED FOR PALLADIUM METALLIZING

RUN #	SUBSTRATE	METAL EVAP AND WT	ALLOY SCHEDULE TEMP °C	TIME (min)	AMBIENT	ETCHANT	ETCH TIME	METHOD OF KPR OR KMER REMOVAL	ETCH RESULTS	BOND CONDITIONS STEP WHERE TEST MADE	WIRE USED FOR BONDING	TIME (SECS)	TEMP °C	APPROX % BONDS	# BONDS ATTEMPTED E	ATTEMPTED B	MADE E	MADE B	BALL WON'T STICK E	BALL WON'T STICK B	METAL LIFTS E	METAL LIFTS B	PULL TESTS SAMPLE SIZE E	SAMPLE SIZE B	FAILED NUMBER E	FAILED NUMBER B	IN SPAN MEAN PULL(g) E	IN SPAN MEAN PULL(g) B
17		Pd THEN ALLOY	480	20	N_2	NONE				ALLOY	.002" Al	10	345		16	10	10	10					10	10	5			
18	1340 WAFERS	1000 mg Pd	600	3	N_2					WAFER AFTER ALLOY	.001" Au	5	345		4	4	4	4					4	4				
19	1340 WAFERS	1000 mg Pd	600	1½	N_2					WAFER AFTER ALLOY	.001" Al	5	345	50									4	5	1	3		
20	1340 WAFERS	1000 mg Pd	600	2	N_2					WAFER AFTER ALLOY	.001" Au	5	345	70									4	5				
21	1340 WAFERS	1000 mg Pd	600	2¼	N_2					WAFER AFTER ALLOY	.001" Al	5	345		10	10	5	0	5	10			3	0				
22	1340 WAFERS	1000 mg Pd	730	¾	N_2					WAFER AFTER ALLOY	.001" Au	5	345	90									7	6	2	5		
23	1340 WAFERS	1500 mg Pd	725	¾	N_2	AQUA REGIA, NO 4TH MASK.	20S	NONE	SATIS	AFTER DIE ATTACH	.001" Au	5	345										9	10	2	2	9.5	5.5
24	4200 WAFERS	1000 mg Pt	725	3	N_2	NONE				WAFER AFTER ALLOY	.002" Au	10	345		12	12	10	9		3	2		10	9	1			
25	4200 WAFERS	1000 mg Pd ALLOY, 8000 mg Pd	700	20	N_2	NONE																						
26	4200 WAFERS	1000 mg Pd, THEN ALLOY, THEN 1000 mg Pd	725	1	ARGON	NONE				WAFER AFTER 2ND EVAP.	.002" Au	5	345	100	25	20	25	20					25	20	24	16		
27			725	3	ARGON	NONE					.002" Au				5	5	1	5					4		1	5		
28	1340 WAFERS	700 mg Pd	725 + 760	3 20	FORM GAS	AQUA REGIA	20S	CHROMIC ACID	SATIS	AFTER DIE ATTACH	.001" Au	10	345	90									10	10				
29	4200 WAFERS	1000 mg Pd ↓ ALLOY ①	740 ①	1	ARGON	AQUA REGIA	20S	NO 4TH	MASK	AFTER DIE ATTACH	.002" Au	5	345	100	30	30	30	30					11	11	9	4	19.8	21.6
30	1741 WAFERS	↓ 1000 mg Pd ↓ ALLOY ②	730 ②	½	ARGON	AQUA REGIA	20S	ACETONE	NOT ALL KMER REMOVED	AFTER DIE ATTACH	.001" Al	5	345	80	50	50	42	38	8	12								
31	1340 WAFERS	1000 mg Pd ↓ ALLOY ① ↓ 1000 mg Pd ↓ ALLOY ③	740 ① 740 ③	1 ½	ARGON ARGON	AQUA REGIA	20S	CHROMIC ACID	SATIS	WAFER AFTER 2ND ALLOY	.001" Au	5	345										5	5				
32	1340 WAFERS	1000 mg Pd ↓ ALLOY ① ↓ 1000 mg Pd ↓ ALLOY ③	725 725	1 ½	ARGON ARGON	AQUA REGIA	20S	CHROMIC ACID	NOT ALL KMER REMOVED	AFTER DIE ATTACH	.001" Au	5	345	0														

PROCESSES AND TESTS USED FOR PALLADIUM METALLIZING

BELOW NUMBER E	BELOW NUMBER B	BALL MEAN PULL(g) E	BALL MEAN PULL(g) B	BELOW NUMBER E	BELOW NUMBER B	METAL MEAN PULL(g) E	METAL MEAN PULL(g) B	AGEING 500C IN N_2 SAMPLE SIZE E	SAMPLE SIZE B	AGE TIME (HRS)	FAILED BELOW BALL E	FAILED BELOW BALL B	FAILED BELOW METAL E	FAILED BELOW METAL B	LEAD WELDING #ATTEMPTED E	#ATTEMPTED B	# SURVIVED E	# SURVIVED B	# FAILED E	# FAILED B	RUN #
5	10																				17
4	4																				18
3	2																				19
4	5																				20
3	0																				21
5	1																				22
5		8		2	8	31	28														23
			9	9	1																24
																					25
1	4																				26
				1	5																27
10	10																				28
1		00		1	7	00	5.1								30	30	30	30			29
															42	38	20	22	20	16	30
5	5																				31
																					32

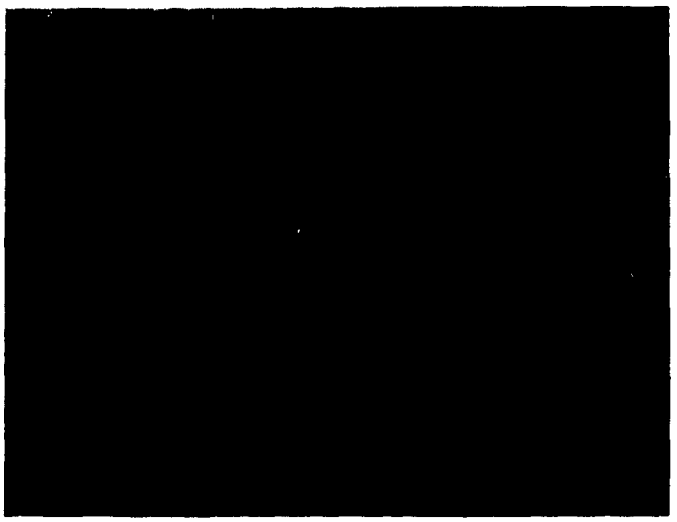
PROCESSES AND TESTS USED FOR PALLADIUM METALLIZING

RUN #	SUBSTRATE	METAL EVAP AND WT	ALLOY SCHEDULE TEMP °C	TIME (MIN)	AMBIENT	ETCHANT	ETCH TIME	METHOD OF KPR OR KMER REMOVAL	ETCH RESULTS	BOND CONDITIONS STEP WHERE TEST MADE	WIRE USED FOR BONDING	TIME (SECS)	TEMP °C	APPROX % BONDS	# BONDS ATTEMPTED E	ATTEMPTED B	MADE E	MADE B	BALL WON'T STICK E	BALL WON'T STICK B	METAL LIFTS E	METAL LIFTS B	PULL TESTS SAMPLE SIZE #UNITS E	SAMPLE SIZE #UNITS B	FAILED IN SPAN NUMBER E	FAILED IN SPAN NUMBER B	MEAN PULL(g) E	MEAN PULL(g) B
33	1340 WAFERS	1000mg Pd ↓ ALLOY ① ↓ 1000mg Pd ↓ ALLOY ②	725	1	ARGON	AQUA REGIA	20S	CHROMIC ACID	CHROMIC DISSOLVED EMITTER Pd KPR STILL ON BASE	AFTER DIE ATTACH	.001 Au	5	345	0														
			725	½	ARGON																							
34	1340 WAFERS	3000mg Pd	725	½	ARGON	NONE				WAFER AFTER ALLOY	.001 Au	5	345	100	20	20	20	20					20	20	20	20		
35			725	¾	ARGON	NONE																						
36			725	1	ARGON	NONE																						
37	1340 WAFERS	3000mg Pd	725	1	ARGON	NONE				WAFER AFTER ALLOY	.001 Au	5	345	0														
38	1340 WAFERS	3000mg Pd	725	½	ARGON	NONE				WAFER AFTER ALLOY	.001 Au	5	345	100									12	9	3	7		
39	1340 WAFERS	3000mg Pd	300	2	N_2	AQUA REGIA	20S	ACETONE	SOME KPR PROBABLY REMAINED	WAFER AFTER ALLOY	.001 Au	5	345	100									8	7	5	7		
										AFTER DIE ATTACH	.001 Au	5	345										1	4	1	1		
40	1340 WAFERS	2000mg Pd	725	30	ARGON	NONE				WAFER AFTER ALLOY				100	136	136	110	110	26	26			8	7	2	7		
41	1340 WAFERS	2000mg Pd	300	2	N_2					WAFER AFTER ALLOY													11	11	10	11		
42	1340 WAFERS	500mg Pd	730	55SECS	ARGON	NONE																						
43	1340 WAFERS	500mg Pd	730	10SEC	ARGON	NONE																						
44	1340 WAFERS	1500mg Pd	730	15SECS	ARGON	NONE																						

PROCESSES AND TESTS USED FOR PALLADIUM METALLIZING

Below Number E	Below Number B	Ball Mean Pull (g) E	Ball Mean Pull (g) B	Below Number E	Below Number B	Metal Mean Pull (g) E	Metal Mean Pull (g) B	Aging 300°C in N_2 Sample Size E	Sample Size B	Age Time (hrs)	Failed Below Ball E	Failed Below Ball B	Below Metal E	Below Metal B	Lead Welding # Attempted E	# Attempted B	# Surviving E	# Surviving B	# Failed E	# Failed B	Run #
																					33
																					34
																					35
																					36
																					37
				9	2																38
				3																	39
	3																				39
				3											110	110	50	50	60	60	40
				1																	41
																					42
																					43
																					44

TASK 1A - EXHIBIT 4



Run #34
3000 mg Pd Evaporated
Alloyed 725°C 1/2 Min
in Argon
Magnification x200

Run #36
3000 mg Pd Evaporated
Alloyed 725°C 1 Min
in Argon
Magnification x200

TABLE SHOWING LONGEST ALLOYING TIMES TO ALLOW PURE PALLADIUM PATTERN SURFACES

AND

SHORTEST ALLOYING TIMES TO PRODUCE PALLADIUM AND SILICON PATTERN SURFACES

VALUES ARE GIVEN AT DIFFERENT ALLOYING TEMPERATURES AND AMOUNTS OF PALLADIUM EVAPORATED.

mg Pd Evaporated	Alloy Temp °C	Longest Alloy Time To Allow Pure Palladium		Shortest Alloy Time To Produce Pd-Si	
		Time	Run #	Time	Run #
500	730	5 Secs		10 Secs	
1000	600			1-1/2 Mins	
1500	730	15 Secs			
2000	480	3 Mins		20 Mins	
3000	300	2 Hours			
3000	725	30 Secs		40 Secs	

SECTION III

TASK 1B - SMALL BALL BONDING

CONTENTS

SECTION III

TASK 1B - SMALL BALL BONDING

D. K. Myers

INTRODUCTION

A program to improve the lead bonding process has been undertaken by Fairchild Semiconductor. Refinements to the process have been made during the first and second quarter and will continue to be made through the third quarter. Improved reliability is anticipated on gold to aluminum bonding strength, lead wire strength, bond positioning and uniformity of ball size. Improved production rates have also been attained.

The essence of the bonding system is to feed a gold wire through a capillary and form a gold ball at the end of the wire by means of a hydrogen flame. The ball is then positioned and indexed with a rocker arm to a transistor element previously attached to a header. The header rests in a temperature regulated heater which provides the necessary heat for gold-aluminum thermal compression bonding. Previously, a wedge type bond was used.

A discussion follows which summarizes, by major area of design, the work through the second quarter of the contract and plans for future periods.

NARRATIVE AND DATA

A. Torch: The torch contains and regulates the hydrogen flame which simultaneously cuts the gold wire and forms a ball for the subsequent bonding operation. Currently, a 2.5 mil orifice diameter pyrex glass torch with a radiused exit and controlled speed cam is in use. A titanium carbide torch* was evaluated and after six hours had to be removed from operation for non-uniform ball size. Figures referred to below may be found in Exhibit 1.

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* TPC-T TiC torch from Tempress Research Co., Inc. (Kentanium(R) K-162B extruded tubing) Kentanium is a registered trademark of Kenanetak Inc., Latrobe, Pa.

Figure 1 is a photomicrograph of the exterior of the used TiC torch - note the discoloration when compared to a new torch, see Figure 2. Figure 3 is a photomicrograph of the orifice end of the used torch shown in Figure 1. The non-uniformity of the ball size was caused by the obstruction of the orifice by foreign material and/or the deposition of eroded material and the resultant obstruction of the orifice. This torch is being metallurgically cross-sectioned to ascertain the nature and substance of the obstruction. The new TiC torch orifice is shown in Figure 4 for comparison purposes. The egg-shaped opening is the result of using Kentanium extruded tubing. Extruded tubing was used as opposed to machining from a solid shape because of cost considerations. Torches fabricated with extruded tubing are 1/5 to 1/4 the cost of machined torches.

B. Capillary: The function of the capillary is to contain the gold wire and to act as a pressure bearing surface on the flame-formed ball so that thermal compression between the gold ball and aluminum contact on the transistor element can be effected. Currently, a pyrex glass capillary, 3/4 inch long, with a .0014 to .0016 inch orifice diameter and a slight radius at the orifice is being used in production of small geometry transistors at Fairchild. Presently, the major problems center around cleanliness of the capillaries and obtaining adequate quality assurance from supplying vendors. Cleanliness of the capillary is an absolute necessity. Dirty capillaries prohibit the threading operation, cause sticking and drag on the gold wire inside the capillary, and reduce the quality of the flame-formed gold ball. Chemical cleaning procedures are being evolved and should help to minimize this problem, but cannot replace good initial quality capillaries from the supplying vendors.

Tungsten carbide capillaries will continue to be evaluated for bonding qualities, life expectancy, and economic aspects. The majority of the work

in this area has been devoted to 2 mil diameter gold wire. The 2 mil wire bonds were evaluated, because a .0025 nominal diameter tungsten carbide capillary was readily available.

Under similar conditions, the tungsten carbide capillary produces a slightly more reliable bond. A summary of the test results follows:

78 Bonded with carbide	78 Bonded with pyrex
1 Ball off	2 Balls off
Base bond at 20 grams	Emitter bond at 13 grams Base bond at 18 grams

The failures were determined by pull testing perpendicular to the plane of the transistor element. The magnitude of the force necessary to break the bond or to exceed the tensile strength of the gold wire was recorded (See Exhibit 2). Only those units having a ball bond failure were considered faulty for purposes of this test. Normally a 4 grams force is considered acceptable.

The same tungsten carbide capillary was used for 4 eight hour days before it had to be cleaned. This cleaning operation is purely mechanical as opposed to a costly chemical cleaning for pyrex capillaries. The WC capillary is produced by machining from a solid piece and is inherently more uniform than a pyrex capillary which is pulled from hot tubing. A tool has been designed and constructed which holds the "dirty" capillary on center for the insertion of a cleaning wire to open the orifice. The above tungsten carbide capillary has been in service for over 400 hours of operation and is continuing to provide adequate service.

A preliminary economic analysis indicates that for 50 working days the cost of pyrex capillaries for one machine, 8 hours per day, is $67.50 (average 8 hour life expectancy) while the cost of the tungsten carbide capillary is approximately $25.00, resulting in an approximate 50% savings.

C. Wire Feed Mechanism: This mechanism must maintain enough back tension on the gold wire as it is unwound from the spool so that the gold ball is firmly held against the capillary as the capillary is indexed onto and retracted from

the die. Currently, a lever tensioning device is being used which incorporates an offset arm that permits spool unreeling in the forward direction but clutches in the reverse direction retracting the wire by gravitational force. (Exhibit 3) A thin walled spool holder using a washer placed eccentrically around the spool axis to conteract spool imbalance is also being used.

D. Mechanized Ball Bonder: Exhibit 4 shows the production model search bonder. Its design incorporates the refinements resulting from two years of experimentation and evaluation at Fairchild Semiconductor.

Initially, non-uniformity of temperature of the heated headers was causing problems. Exhibit 5 shows the header nest and associate equipment. The problem was minimized by employing a space wound heater element which heats non-uniformly and compensates for the variable distances between the heater and the transistor headers.

PROGRAM FOR THE NEXT INTERVAL

A. Torch:- The titanium carbide torch tip shown in Figures 2 and 4 of Exhibit 1 will be further evaluated to determine the effect of an oval orifice on flame control and ball size. Further determination will be made of average expected life for the titanium carbide torch.

B. Capillary:- Tungsten carbide capillaries for 1.1 mil diameter gold wire will be evaluated along with continued evaluation for 2 mil diameter gold wire with respect to cost savings, reliability of gold to aluminum bonds, and improving yields. Heating coils for the tungsten carbide capillaries will also be evaluated.

C. Wire Feed Mechanism:- Incorporation of a small felt cleaning pad to clean the wire prior to entering the capillary will be evaluated.

D. Mechanized Ball Bonder:- Heater improvements will be investigated to further improve the thermal characteristics of the heater block.

FIG 1 - Used TiC Torch
(42X)

FIG 2 - New TiC Torch
(42X)

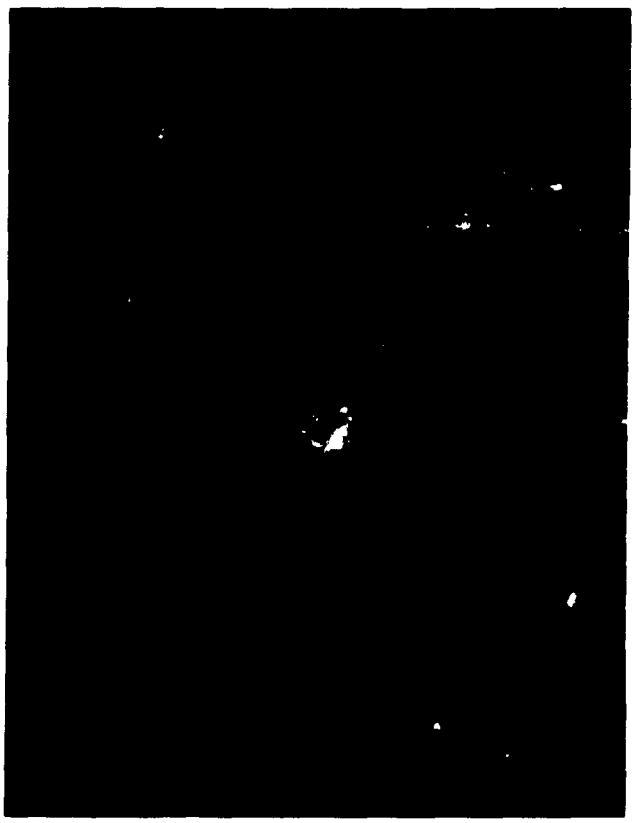


FIG 3 - Used Torch Orifice
(213X)

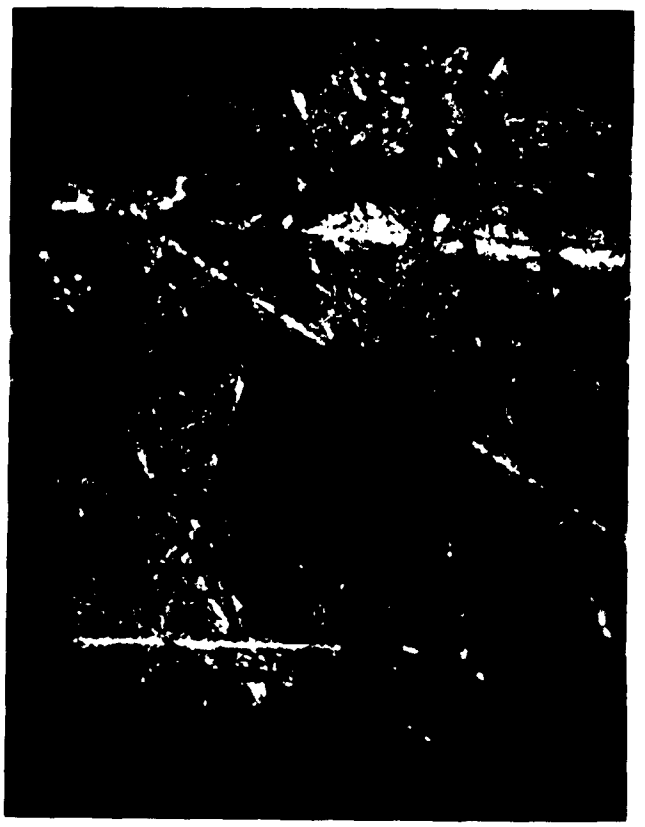


FIG 4 - New Torch Orifice
(213X)

TASK 1B - EXHIBIT 2 (Page 1 of 2)

RESULTS OF PULL TESTS OF BONDS MADE WITH DIFFERENT CAPILLARIES

CONDITIONS: Tungsten Carbide
Temp. 345°C
Cap Wt. 300 Grams
Bond Time 2 Sec

Test #	Base	Emit.	Test #	Base	Emit.
1	21	26	40	18 *	20
2	23	25	41	18	22
3	22	26	42	20	24
4	22	23	43	23	24
5	22	15	44	21	22
6	25	26	45	23	25
7	20 **	22	46	25	27
8	22	25	47	28	24
9	23	24	48	25	26
10	26	26	49	20 *	25
11	24	25	50	26	26
12	23	15 *	51	26	27
13	24	22	52	21	23
14	18	20	53	20	26
15	17	25	54	25	24
16	26	25	55	22	19 *
17	24	26	56	22	15
18	22	24	57	24	25
19	25	23	58	27	25
20	25	23	59	22	27
21	22	20	60	24	25
22	24	26	61	25	23
23	25	25	62	25	25
24	26	27	63	19	23
25	26	28	64	20	23
26	26	25	65	23	21
27	26 *	21	66	20	24
28	21	26	67	25	24
29	18	27	68	20	25
30	28	32	69	26	27
31	22	27	70	23	25
32	20	26	71	17	17
33	28	23	72	21	25
34	26	26	73	22	20
35	20	25	74	23	25
36	25	25	75	20	20
37	24	26	76	21	25
38	26	22	77	20	23
39	27	27 *	78	24	22

* Rebonds ** Ball off

RESULTS OF PULL TESTS OF BONDS MADE WITH DIFFERENT CAPILLARIES

CONDITIONS: Glass
Temp. 345°C
Cap Wt. 300 Grams
Bond Time 2 Sec

Test #	Base	Emit.	Test #	Base	Emit.
1	27 *	25	40	22	23
2	20 *	26	41	14	24
3	23 Cracked Die	22	42	26	22
4	25	22	43	22	23
5	22	18	44	27	28
6	21	24	45	21	20
7	26	25	46	23	19
8	15	27	47	26	24
9	27	24	48	22	23
10	25	22	49	27	25
11	25	24	50	22	26
12	18 **	25	51	20	25
13	27	27	52	26	26
14	22	25	53	24	23
15	21	24	54	22	20
16	24	24	55	19	23
17	24 *	25	56	24	30
18	25	22	57	23	22
19	24	28	58	22	17
20	16	19	59	24	25
21	17	22	60	21	23
22	15	19	61	20 *	21
23	22	23	62	23	25
24	25	23	63	27	26
25	21	25	64	25	26
26	20	25	65	14	20
27	26	25	66	20	19
28	21	25	67	19	20
29	24	13 **	68	24	23
30	19	19	69	18 *	22
31	23	20	70	22	25
32	17	19	71	22	23
33	22	26	72	22	24
34	21	22	73	23	22
35	22	23	74	27	24
36	26	25	75	24	25
37	18	21	76	27	24
38	23	18	77	21	24
39	20	25	78		

ReBonds ** Ball off

TASK 1B - EXHIBIT 3

LEVER CLUTCH WIRE FEED MECHANISM

TASK 1B - EXHIBIT 4

MECHANIZED BALL BONDER

HEATER NEST

SECTION III

TASK 1C - OPTIMIZE CHARACTERISTICS OF

.001 GOLD WIRE FOR CAPILLARY BONDING

CONTENTS

SECTION III

TASK 1C - OPTIMIZE CHARACTERISTICS OF

.001 GOLD WIRE FOR CAPILLARY BONDING

PURPOSE

When .001" diameter hard-drawn gold wire is capillary bonded, it is found that a weak point is formed just above the ball bond. Failure is liable to occur at this point during lead welding or environmental testing.

The purpose of this project is to eliminate the weak point above the ball during the bonding of .001" diameter gold wire.

BACKGROUND

The theory explaining how the weak point is formed above the ball of capillary bonded hard-drawn gold wire is as follows: The wire above the ball is heated by the oxygen flame used to fuse the gold ball. This heating causes annealing and softening of the wire just above the ball. Stresses cause necking and failure of the softened wire in preference to the remaining wire which is hard-drawn.

It was hoped that annealing the gold wire to a softened state prior to capillary bonding would eliminate the weak spot above the gold ball.

Previous work, described in the first report, showed that the strength of bonded, well annealed wire was nearly the same as that of annealed wire prior to bonding. This supported the theory that the formation of the weak spot could perhaps be eliminated by giving the correct annealing treatment to the hard-drawn gold wire.

Some annealed wire with a tensile strength of less than 20,000 psi and % elongation greater than 12% was ordered from two vendors since it was hoped that wire in this highly annealed condition would have desirable bonding properties. Tensile and elongation tests were performed on the received wire.

NARRATIVE AND DATA

Annealing tests were performed on hard-drawn .001" diameter gold wire supplied by Western Gold and Platinum Co., Belmont, California. The spool of hard-drawn wire to be annealed was mounted vertically between bearings so that the spool could rotate freely. The wire was passed through a 750 watt Multiple Unit Hevi Duty Electric Co. tube furnace resting in the horizontal position. The end of the wire was attached to a spool clamped to a shaft. A geared chain drive, connected to a Variac controlled Bodine Electric Co. variable speed motor, was used to rotate the shaft and pull the wire through the furnace. This apparatus allowed the wire to be annealed at variable rates and at variable temperatures.

Initial tests involved annealing samples of the hard-drawn wire at a fixed rate and at different temperatures. It was hoped that the results of these tests would indicate whether further tests were necessary, either at annealing temperatures other than those initially tried or at different rates.

The tensile strength in grams and the elongation over a two inch length were measured for hard-drawn wire and for wires with different annealing schedules. The measurements were made using an Instron Tensile Tester. Two or more tests were made on wire samples from each spool of wire. Capillary bonds were made to dice with aluminum patterns using the differently heat treated wires. Two methods were used to evaluate the pull strengths of the bonded wires.

(1) The bonded wire was pulled with tweezers until fracture, the mounted die being clamped to the measuring arm of a dynamometer. The dynamometer pointer indicated the breaking strength of the wire.

(2) The bonded die, mounted on a header, was clamped in one of the jaws of the Instron Tester. The end of the wire was clamped in the other jaw. A pull test was then performed.

The Instron Tester being a much more sensitive piece of equipment than the dynamometer, it may be assumed that the results obtained by method (2) were more accurate than those obtained by method (1).

A table was drawn up showing the results of the mechanical tests made to the various wires; it will be found as exhibit 1 at the end of this report. Results are shown for hard-drawn wire, for wire annealed to specification by Secon Corp. and Wesgo Co., and for wire annealed here with the apparatus described. The table shows the pull strengths of the wires in the unbonded and the bonded conditions, and the number of tests made. The elongation of the unbonded wire is also shown. Two values are given for the pull strengths of unbonded wires in cases where two separate annealed spools were made at the same alloying schedule. Some blank spaces remain on the table in places where mechanical tests have not yet been performed on the annealed wires.

Another table was made showing the range of pull strengths and elongations which were obtained for wires given different annealing schedules. This will be found as exhibit 2 at the end of this report. The table shows that the range of pull strength and elongation values obtained for any given spool of annealed or un-annealed wires is quite narrow. The fact that the annealed wires displayed uniform mechanical properties within a spool suggests that the apparatus used for annealing is a satisfactory one. The range of pull strengths that occurs on pulling bonded wires from any given spool is much larger. This can partially be explained by the fact that many more tests were used in evaluating a bonded wire than an unbonded wire; it is obvious that the more tests are made the larger the range of values will tend to become. However, it does appear that reproducibility of capillary bonding results is difficult and that large numbers of tests must be made to give statistical evidence from which trends may be seen.

The two tables show that very different mechanical properties were obtained when tests were made on different spools which had supposedly received identical treatment. The difference in mechanical properties of the two randomly selected hard-drawn spools is especially noteworthy. This means that care must be taken in selecting spools of hard-drawn wire with similar mechanical properties for future annealing tests.

It is difficult to draw any valid conclusions from the results available at this time, since more tests must be made. A graph of mean pull strength versus annealing temperature was plotted and will be found as exhibit 3 at the end of this report. The graph is not completely accurate owing to the small test samples. The hard-drawn wire was plotted, for convenience sake, as having been annealed at 25°C. It can be seen that the pull strength of the annealed wire decreased with increasing annealing temperature, as was expected. The tensile strength of the bonded wire remained fairly constant with temperature. At about 500°C the strength of the bonded wire became very similar to that of the unbonded wire.

CONCLUSIONS

Annealing the wire at 500°C at a pull rate through the furnace of 13" per minute caused the bonded and unbonded wires to have very similar properties, thus reducing the occurrence of a weak spot above the ball. Further annealing and mechanical tests must be performed before the exact annealing conditions needed to eliminate the weak point can be found.

PROGRAM FOR NEXT INTERVAL

Further annealing tests will be carried out in order that an annealing schedule may be found which will eliminate the weak point formed above the gold ball in thermal compression bonding.

Metallographic inspection of bonded and unbonded wires will be undertaken. Attempts will be made to observe the deformation and necking that occurs when failure occurs in the region of the gold ball.

TASK 1C - EXHIBIT 1

TABLE SHOWING RANGE OF MECHANICAL PROPERTIES OF DIFFERENT WIRES BEFORE AND AFTER BONDING

Wire Vendor	Annealed Condition	Before Bonding			Bonded Pull Strength			
					Dynamometer		Instron	
		Number of Pulls	Pull Strength (g) Range	El % Range	Pull Strength (g) Range	Number of Pulls	Pull Strength (g) Range	Number of Pulls
Wesgo	Hard-Drawn	2 4	.7 .9	.05 .2	3.7	16	3.8	8
Secon	As received FTU < 20,000 psi % El > 12%	2	.3	1.0				
Wesgo	As received FTU < 20,000 psi % El > 12%	2	.3	0				
Wesgo	Annealed 583°C	2 4	0 1.2	1.0 .5	2.5	10	.7	9
Wesgo	Annealed 422°C	4	.7	3.5	2.3	13	1.0	10

TASK 1C - EXHIBIT 2

TABLE SHOWING MECHANICAL PROPERTIES OF WIRES BEFORE AND AFTER CAPILLARY BONDING

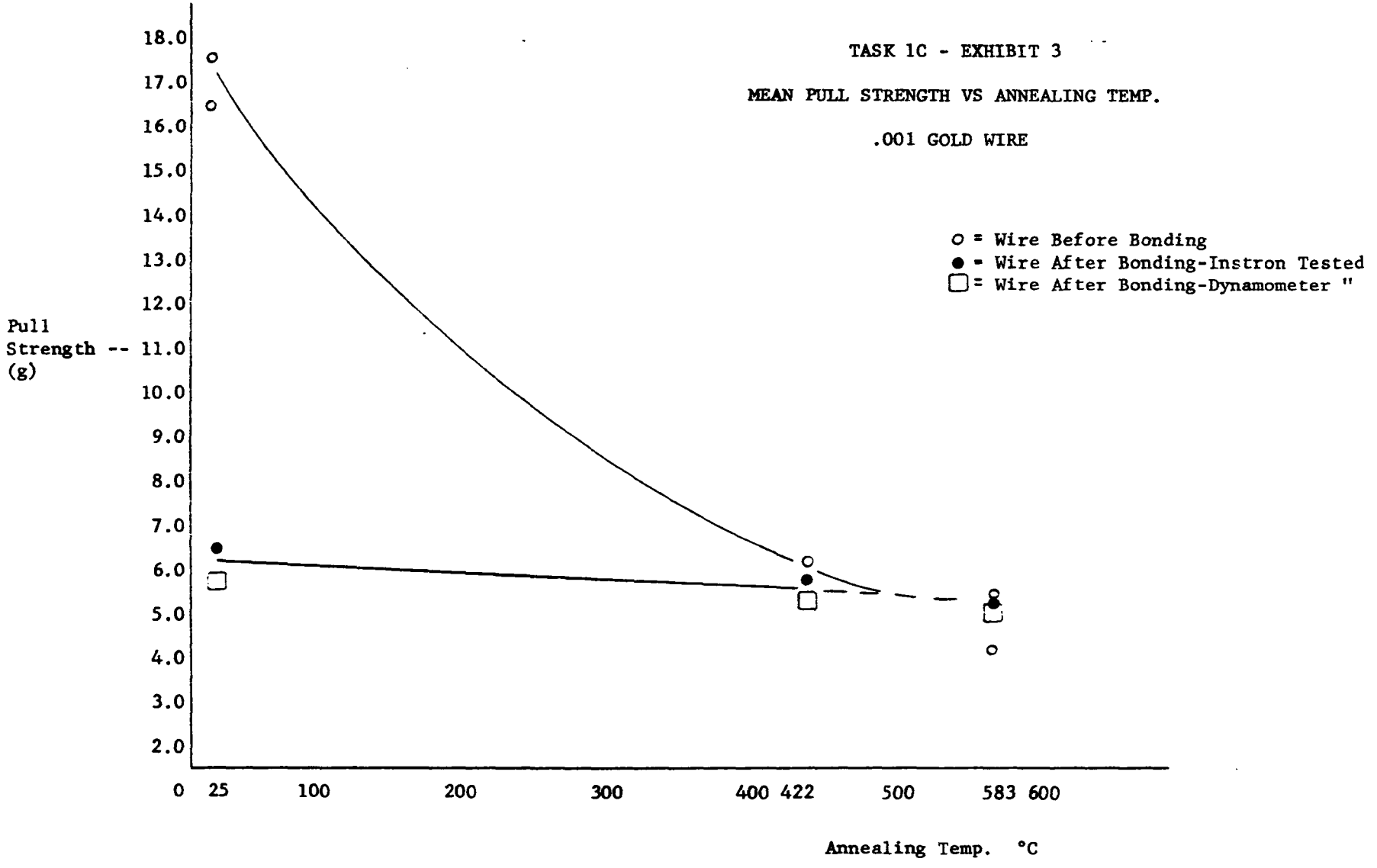
Wire	Annealed Condition	Pull Tests (Instron) Before Bond Pull Strength (gms) Mean	Range	No. of Pulls	% Elongn Mean	Range	Bonded Pull Tests (Dynamometer) Number Bonds Pulled	Pull Strength (g) Mean	Range	Bonded Pull Tests (Instron) Number Bonds Pulled	Pull Strength (g) Mean	Range
.001" Wesgo	Hard-Drawn	16.8 17.6	16.5-17.2 17.0-17.9	2 4	.42 .8	.40-.45 .6 -.8	16	5.84	4.0-7.7	8	6.4	3.8-7.6
.001" Secon	As per spec El > 12% UTS 20,000 psi	7.2	7.1- 7.4	2	9.0	8.5-9.5						
.001" Wesgo	"	8.3	8.2- 8.5	2	12	12-12						
.001" Wesgo	" 583°C	4.3 5.9	4.3- 4.3 5.2- 6.4	2 4	6.5 9.1	6- 7 9.0-9.5	10	5.7	4.5-7.0	9	5.8	5.4-6.1
.001" Wesgo	" 422°C	6.3	5.9- 6.6	4	9.0	7.5-11.0	13	5.13	4.7-7.0	10	6.7	6.1-7.1
.001" Wesgo	" 600°C											
.001" Wesgo	" 485°C											
.001" Wesgo	" 538°C											

Rate of Pulling Wire Through Furnace = 13"/Min
Bonds Were Made to the Emitter Dots of 4200 Units.

TASK 1C - EXHIBIT 3

MEAN PULL STRENGTH VS ANNEALING TEMP.

.001 GOLD WIRE



SECTION III

TASK 1D - ULTRASONIC BONDING

CONTENTS

SECTION III

TASK 1D - ULTRASONIC BONDING

W. J. Warren

PURPOSE

The purpose of this work is to develop a method of bonding pattern metal to lead wire by means other than thermal compression. The method should be insensitive to the surface condition of the metals being joined and should not have a critical bonding temperature.

Ultrasonic welding fulfills the above criteria and has been chosen for investigation.

BACKGROUND

In the first period ultrasonic bonds were made between .001" aluminum 1% Si wire and aluminized dice. However, the bonds made were not of reproducible high mechanical strength.

PROGRESS DURING THIS PERIOD

A new, more sophisticated assembly was received during this period for housing the transducer coupling assembly and holding the sonotrode, and was found to operate satisfactorily. (See exhibit 2)

Some of the .001" diameter aluminum 1% silicon wire was annealed by pulling it through a tube furnace with a hot zone temperature of 500°C; the rate of pulling was 13" per minute. This softened the wire considerably. As mentioned in the last report

$H^{3/2}T^{3/2} = KE$ (according to verbal communication from Sonobond Borp.)

where H hardness of the wire (Vickers)
T thickness
K constant
E energy for ultrasonic bonding.

Annealing the wire should therefore reduce the energy necessary for ultrasonic welding.

Some bonds were made to small geometry units which were then given standard in-plant centrifuge tests at 40,000 g's, two positions for two minutes.

It can be seen from the results given in Exhibit 1 that some bond failures occurred owing to stresses involved in bending the bonded wires for lead welding. The cans were cut off the units after centrifuging and the units visually inspected for bond failure. No failures due to acceleration were observed, showing that the bonds were of considerable mechanical strength. However, it would be desirable to produce bonds of sufficient strength that they would all survive lead welding.

It was decided to introduce the dynamometer pull test as a means of evaluation of ultrasonic bond strength. The pull strength of a bonded unit was found by clamping a lead bonded, but not welded, unit to the dynamometer measuring arm. The bonded wire was then pulled with tweezers in the direction of rotation of the measuring arm until bond or wire failure occurred. The dynamometer dial registered the breakage strength. For the tests described below the units were clamped so that the wires were pulled in a direction in line with the bond and parallel to the header surface.

Bonds were made to large geometry units(as a test bed due to the convenience of large bond area) with both unannealed and annealed .001" AlSi 1% wires. The settings used were those reported last period to be optimum for the bonding of hard drawn aluminum wire. Several different types of sonotrodes were used so that their effect on the pull strength of ultrasonic bonds might be determined. It was found that bonds could be made at least 90% of the time with both unannealed and annealed wires and with all the different sonotrodes. It was found, in contradiction to that reported in the previous period, that ungrooved sonotrodes were satisfactory, provided care was taken to make the sonotrode face and die parallel. The results of dynamometer pull tests using different sonotrodes, annealed and unannealed wires, are shown in exhibit 1. When the pull tests were performed, it was noted whether bond failure occurred in the span of the wire, at the bond interface, or at the angle between the bonded and unbonded wire. This latter region was particularly liable to failure owing to the sudden change

in wire cross section at this point, and also because any movement in the wire caused fatigue at this point. The same failure mechanism is liable to occur in thermal compression wedge bonds.

A mean pull strength of 3.8 grams has been obtained for wedge bonds of .001" AlSi 1% to ten small geometry units. Each of the four ultrasonic bonding tests gave higher mean pull strengths than were obtained for the thermal compression wedge bonds. Other interesting results may be seen from the tables at the end of this report. Very few failures occurred at the bond itself in any of the tests. It may be seen that the mean pull strength of those tests which used hard drawn wire was about four times higher than those using the annealed wire. The tensile strength of the wire was reduced by the annealing treatment to such an extent that in-span failure was easily the most common failure mode. However, where hard drawn wire was used most failures occurred at the angle between bonded and unbonded wire. It was not possible to discover from the results whether the annealed or hard-drawn wire gave stronger ultrasonic bonds, since bond failure at the bonded interface was so infrequent.

It seemed possible to conclude that ultrasonic bonds were stronger than wedge bonds. Also, that hard drawn wire was preferable to the highly annealed wire used in other tests.

CONCLUSIONS Ultrasonic bonds can be produced between .001" AlSi 1% wire and and aluminized dice which are stronger than thermal compression wedge bonds.

It is not yet known whether annealed or hard-drawn wire gives stronger bonds at the wire-dice interface. However, highly annealed wire is weaker in the span of the wire than at the bond; therefore, hard-drawn wire is preferable to highly-annealed wire.

PROGRAM FOR NEXT INTERVAL

Different annealing schedules will be tried to see if less than fully annealed wire will give improved bonding characteristics.

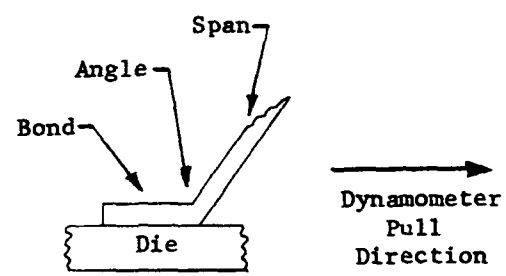
A large number of ultrasonic bonds will be made in order that further strengths and in-plant environmental tests may be performed.

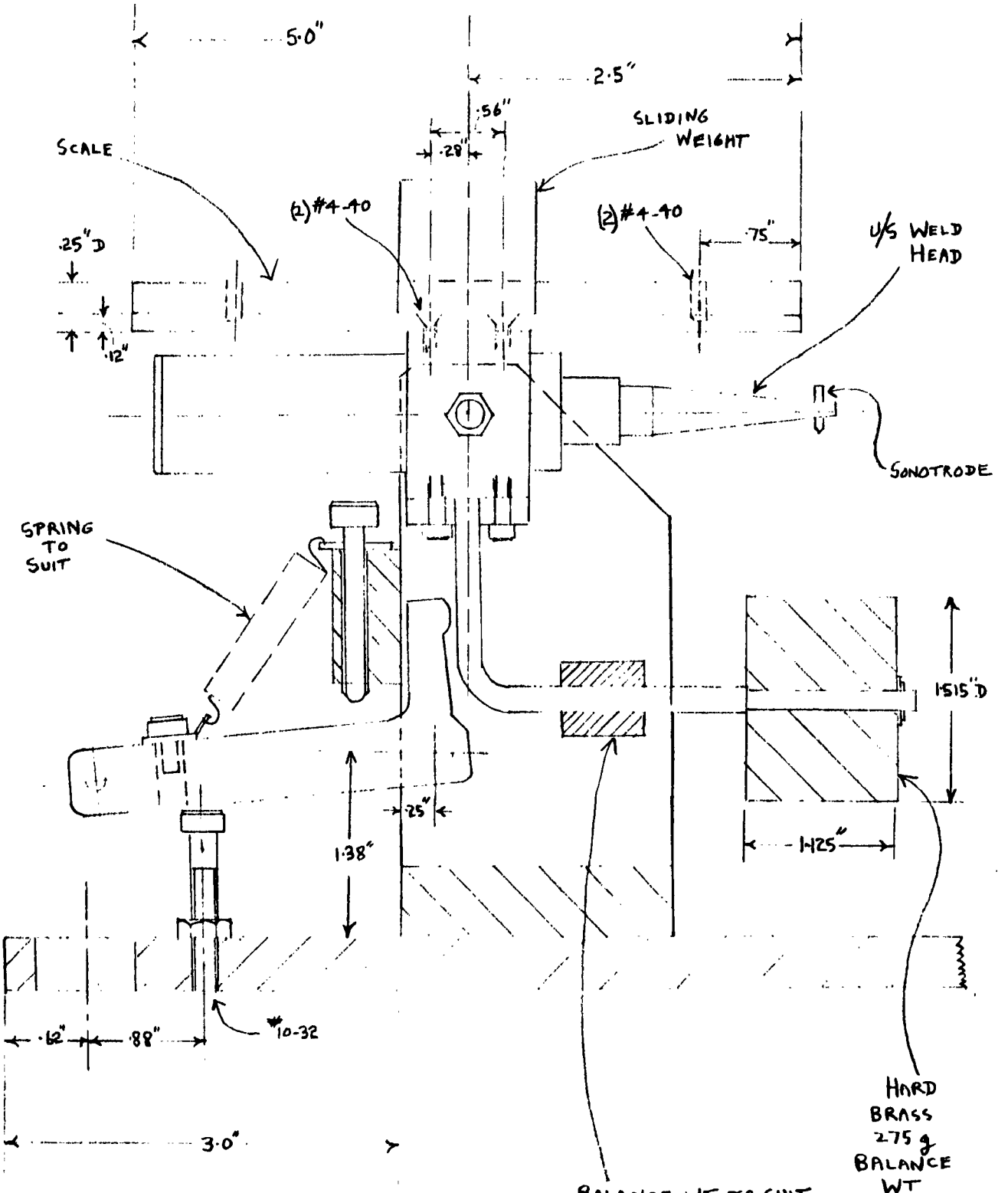
TASK 1D - EXHIBIT 1
DYNAMOMETER PULL TEST RESULTS

Type of Sonotrode	Type of Wire	Broke in Span				Broke at Angle Between Bonded and Span Wire				Broke at Bond				Total	
		Emitter		Base		Emitter		Base		Emitter		Base			
		Number	Mean Pull(g)	Number	Mean Pull(g)	Number	Mean Pull(g)	Number	Mean Pull(g)	Number	Mean Pull(g)	Number	Mean Pull(g)	Number	Mean Pull(g)
Grooved Wedge (F=.005)	Annealed	7	4.6	6	4.4	4	3.5	2	2.5	0	-	0	-	19	4.1
Grooved Wedge (F=.002)	Hard Drawn	0	-	2	19.5	10	16.1	8	16.3	0	-	0	-	20	16.5
Ungrooved Wedge	Annealed	8	4.0	11	4.4	1	2.5	1	3.8	1	1.5	0	-	22	4.0
Ungrooved Wedge	Hard Drawn	1	18.5	2	21.0	9	19.3	9	18.7	0	-	2	9.5	23	18.3

<u>Settings Used to Make Bonds.</u>

Load applied to Sonotrode tip = 250 on sliding scale
Sonoweld Model No. W-20-TSL settings:
Resonance setting = +30
Power = 0.4 watts
Time = 1.5 secs.





SKETCH OF MOUNTING FOR TRANSDUCER- COUPLER ASSEMBLY

SECTION III

TASK 1E - DYNAMIC AND STEP STRESS TESTING

CONTENTS

SECTION III

TASK 1E-DYNAMIC AND STEP STRESS TESTING

J. A. Corzine

SUMMARY OF WORK IN THIS PERIOD

Thermal Shock and Vibration testing were tentatively completed this period. Shock testing is awaiting the "debugging" and Acceptance Performance Testing of the prototype Avco Shock Tower recently delivered. Phase II of Constant Acceleration testing is now underway after redesign of inserts for the large sample size rotor. The Step-stress Program is in progress with little difficulty encountered.

DYNAMIC TESTING - NARRATIVE AND DATA

Thermal Shock

The thermal shock portion of this contract was completed during this quarter. Five failures were encountered from a sample size of 100 units. All failures occurred in the first 25 cycles of this test. It is significant to note that if a unit withstands 25 thermal shock cycles between -65°C and +150°C, this test indicates that it will survive prolonged temperature cycling. These units underwent a total of 70 hours of thermal cycle temperatures.

As discussed in the last quarterly report, a great number of difficulties were encountered with this portion of the contract. We reported that an ink had been found to serialize the units that would withstand the attack of the cold liquid (Trichlorethylene). In the process of completing the last period of thermal shock (400 cycles) the serial numbers were removed by the liquid cooling medium. In short tests, the ink had proven satisfactory; however, due to the long exposure to the trichlorethylene during the 400 cycles, the identity of individual units was lost making a final parameter readout of little value.

Final parameter testing did indicate that h_{FE} does degrade to some extent under prolonged thermal shock conditions. Assumptions only can be made from the parameter data compiled; however, average h_{FE} value for the sample had

degraded approximately 20% between initial and post testing. This subject will be discussed below in the Deviations From Program Outline section of this report.

Conclusion: Thermal shock when conducted between the temperatures -65°C and +150°C with units experiencing a time at room temperature between immersions no longer than 30 seconds is a practical, expedient method of determining which devices are not representative of the true manufacturing process. This test may provide a failure rate of suitable magnitude that a statistical analysis can be applied to comparisons of production processes or competitive manufacturer's products. The results of this test corroborate the fact that this test need not be of a large magnitude. The results of 25 thermal cycles provided as much data as did the full 800 cycles of this test. In fact, a test shorter than 25 cycles may provide as much data as can be obtained from large number of cycles. Results of thermal shock tests are presented in exhibit 1.

Constant Acceleration (Centrifuge)

The centrifuge rotor used for "G" levels between 50,000 and 150,000 "G's" for sample sizes larger than six units was not equipped with inserts to accept TO-18 size units at the initiation of this Program. An experiment was conducted into the feasibility of Teflon as a material for use as rotor inserts. A series of tests was made after Teflon inserts were designed and manufactured for this rotor. The tests indicated that after a few minutes at 100,000 "G's" the inserts became plastic and malleable even to the point of allowing one unit to pass through the insert and lodge against the rotor wall.

Inserts of aluminum have been designed and tested. The delivery of these aluminum inserts has delayed Phase II of this portion. These inserts are now in use and centrifuging for Phase II is now underway.

Shock

The Prototype Shock Tower was delivered this quarter. Testing of the tower revealed that the piston and cylinder assembly were not operating to design specifications. Replacement of the cylinder assembly disclosed the original

unit had failed due to the many hours of testing it had undergone before delivery. The tower then met design requirements, but another problem was encountered. At present this shock tower does not possess the repeatability deemed necessary for a controlled experiment. "G" levels will vary 15% with all controls remaining constant. Intensive effort is being applied to overcome this problem. Preliminary shock testing has indicated that the area of interest for these tests is in the 10,000 to 15,000 "G" level range. This information is in conflict with the 5,000 "G" level originally estimated. Changes to the Program outline to investigate this range are discussed below.

Vibration

Due to mass limitations of the shaker table of our vibration machine, the units for vibration were divided into three groups; 216 units were mounted in a cube (36 units in each orientation) and vibrated for 96 hours at the "G" level outlined in our original plan. No failures were encountered.

Since the drafting of our plan, Fairchild Semiconductor has purchased an Unholtz-Dickie Sinusoidal-Complex-Random Vibration machine. This new machine was built to Fairchild specifications incorporating the facility of programming random vibration on top of the sinusoidal wave with "G" levels ten times those outlined in the original plan. Since our primary objective was to produce a failure rate from which devices could be evaluated, and no failures resulted from the testing of the first group, we decided to run the second test group at the maximum capabilities of the new vibration equipment.

The second group (216 units, 36 in each orientation) underwent 96 hours of sinusoidal vibration with Gaussian random vibration programmed on top of the sinusoidal wave. The sinusoidal vibration frequency was varied logarithmically between 20 and 2,000 cps. with a sweep time of ten minutes. Amplitude at maximum peak acceleration was 46 "G". This test produced no failures.

Conclusion: Vibration testing is not an expedient means of evaluating silicon planar epitaxial transistors. The equipment available in the vibration field is not destructive to this type device.

We do not plan to test the remaining 168 units. Results of vibration tests are presented in exhibit 2.

STEP-STRESS PROGRAM - NARRATIVE AND DATA

The Step-stress Program is in progress at the present time. Fairchild had completed a Step-stress Program on a similar device immediately prior to the start of this contract. Some valuable data were obtained from the prior test. These test results indicated that one-hour, three-hour and nine-hour increments of time-under-stress are not of sufficient length to allow operating power or storage temperature to effect a silicon device. Temperatures far in excess of the die-attach temperatures used on the production line were applied before failures were encountered. Engineering judgment dictated that the approach to testing under this contract be modified to obtain the objective of this test. Time periods of 9, 27 and 81 hours were determined to be of enough duration to allow the devices to stabilize at the power and temperature levels applied. This program is being conducted on these intervals.

A visit to Fairchild by technical representatives of the Army Electronic Materiel Agency resulted in changes in this program. The representatives believed that the stress levels of the operating power portion of this program were not high enough to provide data expediently. It was decided that a large increase should be made from the 480 mW that we were then testing at to 600 mW on the 81-hour testing. The accompanying chart reflects this change. (Exhibit 3). It was also decided that 27-hour testing should be started immediately at 600 mW rather than waiting for a failure rate to develop on the long-term tests to indicate the stress level of interest, and the 9-hour tests would begin at 600 mW also. The size of increases of power in the steps was also changed to 40 mW. The storage temperature portion was verified as having reached the area of interest; therefore no changes other than the time increments were made from the original proposal.

Exhibit 3 outlines the Step-stress Program. Progress to date is also noted on the exhibit.

SUMMARY OF DEVIATIONS FROM THE PROGRAM OUTLINE

1. Vibration testing has been terminated after testing was completed on 432 units of a total sample of 600, because no failure rate was established even after the stress level was raised on 216 of these units by a power of ten.
2. Shock testing will be raised from 5,000 "G's" to 15,000 "G's" with a pulse duration of .1 millisecond. Acceptance tests of the new shock tower using similar units indicate the area of interest for shock testing is between 10,000 and 15,000 "G's". Tests will be conducted starting at 15,000 "G's" and decreasing in steps of 1,000 "G's". Procedure will remain as outlined in the original plan, only the stress levels are changed.
3. Time-under-stress periods for the Step-stress Program will be changed from 1, 3 and 9-hour tests to 9, 27 and 81 hour intervals. All of the above changes are discussed above in the narrative portion of this report.
4. Results from the Thermal Shock testing indicate a need for breaking the first 25-cycle test into smaller increments to determine if the failure rate established from the data compiled from the 25-cycle test might not have been, in fact, from the first five or ten cycles of this test. We plan, when this portion is rerun on the improved device, to use 5-cycle intervals until 25 cycles are reached in order to verify this hypothesis. We also plan to lower the maximum number of cycles to 100 because no usable data was generated on the first test beyond 25 cycles.

TASK 1E - EXHIBIT 1
SIGNAL CORPS CONTRACT

Thermal Shock

Type 2N914

Start Date_____
Completion Date_____

Unit No.	Period I 25 Cycles		Period II 25 Cycles		Period III 50 Cycles		Period IV 100 Cycles		Period V 200 Cycles		Period VI 400 Cycles	
	Leak Rate	Open Short	Leak Rate	Open Short	Leak Rate	Open Short	Leak Rate	Open Short	Leak Rate	Open Short	Leak Rate	Open Short
3001	Okay	Okay	Okay	Okay	Okay	Okay	Okay	Okay	Okay	Okay	Okay	Okay
3002	"	"	"	"	"	"	"	"	"	"	"	"
3003	"	"	"	"	"	"	"	"	"	"	"	"
3004	"	"	"	"	"	"	"	"	"	"	"	"
3005	"	"	"	"	"	"	"	"	"	"	"	"
3006	"	"	"	"	"	"	"	"	"	"	"	"
3007	"	"	"	"	"	"	"	"	"	"	"	"
3008	"	"	"	"	"	"	"	"	"	"	"	"
3009	"	"	"	"	"	"	"	"	"	"	"	"
3010	"	"	"	"	"	"	"	"	"	"	"	"
3011	"	"	"	"	"	"	"	"	"	"	"	"
3012	"	"	"	"	"	"	"	"	"	"	"	"
3013	"	"	"	"	"	"	"	"	"	"	"	"
3014	Failed											
3015	Okay	Okay	Okay	Okay	Okay	Okay	Okay	Okay	Okay	Okay	Okay	Okay
3016	"	"	"	"	"	"	"	"	"	"	"	"
3017	"	"	"	"	"	"	"	"	"	"	"	"
3018	"	"	"	"	"	"	"	"	"	"	"	"
3019	"	"	"	"	"	"	"	"	"	"	"	"
3020	"	"	"	"	"	"	"	"	"	"	"	"
3021	"	"	"	"	"	"	"	"	"	"	"	"
3022	"	"	"	"	"	"	"	"	"	"	"	"
3023	"	"	"	"	"	"	"	"	"	"	"	"
3024	"	"	"	"	"	"	"	"	"	"	"	"
3025	"	"	"	"	"	"	"	"	"	"	"	"
3026	Failed											
3027	Failed											
3028	Okay	Okay	Okay	Okay	Okay	Okay	Okay	Okay	Okay	Okay	Okay	Okay
3029	"	"	"	"	"	"	"	"	"	"	"	"
3030	"	"	"	"	"	"	"	"	"	"	"	"
3031	"	"	"	"	"	"	"	"	"	"	"	"
3032	"	"	"	"	"	"	"	"	"	"	"	"
3033	"	"	"	"	"	"	"	"	"	"	"	"
3034	"	"	"	"	"	"	"	"	"	"	"	"
3035	"	"	"	"	"	"	"	"	"	"	"	"
3036	"	"	"	"	"	"	"	"	"	"	"	"
3037	"	"	"	"	"	"	"	"	"	"	"	"
3038	"	"	"	"	"	"	"	"	"	"	"	"
3039	"	"	"	"	"	"	"	"	"	"	"	"
3040	"	"	"	"	"	"	"	"	"	"	"	"
3041	"	"	"	"	"	"	"	"	"	"	"	"
3042	"	"	"	"	"	"	"	"	"	"	"	"
3043	"	"	"	"	"	"	"	"	"	"	"	"
3044	"	"	"	"	"	"	"	"	"	"	"	"
3045	"	"	"	"	"	"	"	"	"	"	"	"
3046	"	"	"	"	"	"	"	"	"	"	"	"
3047	"	"	"	"	"	"	"	"	"	"	"	"
3048	"	"	"	"	"	"	"	"	"	"	"	"
3049	"	"	"	"	"	"	"	"	"	"	"	"
3050	"	"	"	"	"	"	"	"	"	"	"	"

TASK 1E - EXHIBIT 1
SIGNAL CORPS CONTRACT

Thermal Shock

Type 2N914

Start Date_____
Completion Date_____

Unit No.	Period I 25 Cycles		Period II 25 Cycles		Period III 50 Cycles		Period IV 100 Cycles		Period V 200 Cycles		Period VI 400 Cycles	
	Leak Rate	Open Short	Leak Rate	Open Short	Leak Rate	Open Short	Leak Rate	Open Short	Leak Rate	Open Short	Leak Rate	Open Short
3051	Okay	Okay	Okay	Okay	Okay	Okay	Okay	Okay	Okay	Okay	Okay	Okay
3052	"	"	"	"	"	"	"	"	"	"	"	"
3053	"	"	"	"	"	"	"	"	"	"	"	"
3054	"	"	"	"	"	"	"	"	"	"	"	"
3055	"	"	"	"	"	"	"	"	"	"	"	"
3056	"	"	"	"	"	"	"	"	"	"	"	"
3057	"	"	"	"	"	"	"	"	"	"	"	"
3058	Failed											
3059	Okay	Okay	Okay	Okay	Okay	Okay	Okay	Okay	Okay	Okay	Okay	Okay
3060	"	"	"	"	"	"	"	"	"	"	"	"
3061	Failed											
3062	Okay	Okay	Okay	Okay	Okay	Okay	Okay	Okay	Okay	Okay	Okay	Okay
3063	"	"	"	"	"	"	"	"	"	"	"	"
3064	"	"	"	"	"	"	"	"	"	"	"	"
3065	"	"	"	"	"	"	"	"	"	"	"	"
3066	"	"	"	"	"	"	"	"	"	"	"	"
3067	"	"	"	"	"	"	"	"	"	"	"	"
3068	"	"	"	"	"	"	"	"	"	"	"	"
3069	"	"	"	"	"	"	"	"	"	"	"	"
3070	"	"	"	"	"	"	"	"	"	"	"	"
3071	"	"	"	"	"	"	"	"	"	"	"	"
3072	"	"	"	"	"	"	"	"	"	"	"	"
3073	"	"	"	"	"	"	"	"	"	"	"	"
3074	"	"	"	"	"	"	"	"	"	"	"	"
3075	"	"	"	"	"	"	"	"	"	"	"	"
3076	"	"	"	"	"	"	"	"	"	"	"	"
3077	"	"	"	"	"	"	"	"	"	"	"	"
3078	"	"	"	"	"	"	"	"	"	"	"	"
3079	"	"	"	"	"	"	"	"	"	"	"	"
3080	"	"	"	"	"	"	"	"	"	"	"	"
3081	"	"	"	"	"	"	"	"	"	"	"	"
3082	"	"	"	"	"	"	"	"	"	"	"	"
3083	"	"	"	"	"	"	"	"	"	"	"	"
3084	"	"	"	"	"	"	"	"	"	"	"	"
3085	"	"	"	"	"	"	"	"	"	"	"	"
3086	"	"	"	"	"	"	"	"	"	"	"	"
3087	"	"	"	"	"	"	"	"	"	"	"	"
3088	"	"	"	"	"	"	"	"	"	"	"	"
3089	"	"	"	"	"	"	"	"	"	"	"	"
3090	"	"	"	"	"	"	"	"	"	"	"	"
3091	"	"	"	"	"	"	"	"	"	"	"	"
3092	"	"	"	"	"	"	"	"	"	"	"	"
3093	"	"	"	"	"	"	"	"	"	"	"	"
3094	"	"	"	"	"	"	"	"	"	"	"	"
3095	"	"	"	"	"	"	"	"	"	"	"	"
3096	"	"	"	"	"	"	"	"	"	"	"	"
3097	"	"	"	"	"	"	"	"	"	"	"	"
3098	"	"	"	"	"	"	"	"	"	"	"	"
3099	"	"	"	"	"	"	"	"	"	"	"	"
3100	"	"	"	"	"	"	"	"	"	"	"	"

TASK 1E - EXHIBIT 2
SIGNAL CORPS CONTRACT

Start Date_____
Completion Date_____

Vibration Test

Type 2N914

Unit No.	20-2000-20 Cycle Time	Period I 3 Hrs	Period II 3 Hrs	Period III 6 Hrs	Period IV 12 Hrs	Period V 24 Hrs	Period VI 48 Hrs
4001	10 Min.	Unit Good	Unit Good	Unit Good	Unit Good	Unit Good	Unit Good
4002	"	"	"	"	"	"	"
4003	"	"	"	"	"	"	"
4004	"	"	"	"	"	"	"
4005	"	"	"	"	"	"	"
4006	"	"	"	"	"	"	"
4007	"	"	"	"	"	"	"
4008	"	"	"	"	"	"	"
4009	"	"	"	"	"	"	"
4010	"	"	"	"	"	"	"
4011	"	"	"	"	"	"	"
4012	"	"	"	"	"	"	"
4013	"	"	"	"	"	"	"
4014	"	"	"	"	"	"	"
4015	"	"	"	"	"	"	"
4016	"	"	"	"	"	"	"
4017	"	"	"	"	"	"	"
4018	"	"	"	"	"	"	"
4019	"	"	"	"	"	"	"
4020	"	"	"	"	"	"	"
4021	"	"	"	"	"	"	"
4022	"	"	"	"	"	"	"
4023	"	"	"	"	"	"	"
4024	"	"	"	"	"	"	"
4025	"	"	"	"	"	"	"
4026	"	"	"	"	"	"	"
4027	"	"	"	"	"	"	"
4028	"	"	"	"	"	"	"
4029	"	"	"	"	"	"	"
4030	"	"	"	"	"	"	"
4031	"	"	"	"	"	"	"
4032	"	"	"	"	"	"	"
4033	"	"	"	"	"	"	"
4034	"	"	"	"	"	"	"
4035	"	"	"	"	"	"	"
4036	"	"	"	"	"	"	"
4037	"	"	"	"	"	"	"
4038	"	"	"	"	"	"	"
4039	"	"	"	"	"	"	"
4040	"	"	"	"	"	"	"
4041	"	"	"	"	"	"	"
4042	"	"	"	"	"	"	"
4043	"	"	"	"	"	"	"
4044	"	"	"	"	"	"	"
4045	"	"	"	"	"	"	"
4046	"	"	"	"	"	"	"
4047	"	"	"	"	"	"	"
4048	"	"	"	"	"	"	"
4049	"	"	"	"	"	"	"
4050	"	"	"	"	"	"	"
4051	"	"	"	"	"	"	"
4052	"	"	"	"	"	"	"
4053	"	"	"	"	"	"	"

TASK 1E - EXHIBIT 2
SIGNAL CORPS CONTRACT

Start Date_____
Completion Date_____

Vibration Test

Type 2N914

Unit No.	20-2000-20 Cycle Time	Period I 3 Hrs	Period II 3 Hrs	Period III 6 Hrs	Period IV 12 Hrs	Period V 24 Hrs	Period VI 48 Hrs
4054	10 Min.	Unit Good	Unit Good	Unit Good	Unit Good	Unit Good	Unit Good
4055	"	"	"	"	"	"	"
4056	"	"	"	"	"	"	"
4057	"	"	"	"	"	"	"
4058	"	"	"	"	"	"	"
4059	"	"	"	"	"	"	"
4060	"	"	"	"	"	"	"
4061	"	"	"	"	"	"	"
4062	"	"	"	"	"	"	"
4063	"	"	"	"	"	"	"
4064	"	"	"	"	"	"	"
4065	"	"	"	"	"	"	"
4066	"	"	"	"	"	"	"
4067	"	"	"	"	"	"	"
4068	"	"	"	"	"	"	"
4069	"	"	"	"	"	"	"
4070	"	"	"	"	"	"	"
4071	"	"	"	"	"	"	"
4072	"	"	"	"	"	"	"
4073	"	"	"	"	"	"	"
4074	"	"	"	"	"	"	"
4075	"	"	"	"	"	"	"
4076	"	"	"	"	"	"	"
4077	"	"	"	"	"	"	"
4078	"	"	"	"	"	"	"
4079	"	"	"	"	"	"	"
4080	"	"	"	"	"	"	"
4081	"	"	"	"	"	"	"
4082	"	"	"	"	"	"	"
4083	"	"	"	"	"	"	"
4084	"	"	"	"	"	"	"
4085	"	"	"	"	"	"	"
4086	"	"	"	"	"	"	"
4087	"	"	"	"	"	"	"
4088	"	"	"	"	"	"	"
4089	"	"	"	"	"	"	"
4090	"	"	"	"	"	"	"
4091	"	"	"	"	"	"	"
4092	"	"	"	"	"	"	"
4093	"	"	"	"	"	"	"
4094	"	"	"	"	"	"	"
4095	"	"	"	"	"	"	"
4096	"	"	"	"	"	"	"
4097	"	"	"	"	"	"	"
4098	"	"	"	"	"	"	"
4099	"	"	"	"	"	"	"
4100	"	"	"	"	"	"	"
4101	"	"	"	"	"	"	"
4102	"	"	"	"	"	"	"
4103	"	"	"	"	"	"	"
4104	"	"	"	"	"	"	"
4105	"	"	"	"	"	"	"
4106	"	"	"	"	"	"	"

TASK 1E - EXHIBIT 2
SIGNAL CORPS CONTRACT

Vibration Test

Start Date_____
Completion Date_____

2N914

Unit No.	20-2000-20 Cycle Time	Period I 3 Hrs	Period II 3 Hrs	Period III 6 Hrs	Period IV 12 Hrs	Period V 24 Hrs	Period VI 48 Hrs
4107	10 Min.	Unit Good	Unit Good	Unit Good	Unit Good	Unit Good	Unit Good
4108	"	"	"	"	"	"	"
4109	"	"	"	"	"	"	"
4110	"	"	"	"	"	"	"
4111	"	"	"	"	"	"	"
4112	"	"	"	"	"	"	"
4113	"	"	"	"	"	"	"
4114	"	"	"	"	"	"	"
4115	"	"	"	"	"	"	"
4116	"	"	"	"	"	"	"
4117	"	"	"	"	"	"	"
4118	"	"	"	"	"	"	"
4119	"	"	"	"	"	"	"
4120	"	"	"	"	"	"	"
4121	"	"	"	"	"	"	"
4122	"	"	"	"	"	"	"
4123	"	"	"	"	"	"	"
4124	"	"	"	"	"	"	"
4125	"	"	"	"	"	"	"
4126	"	"	"	"	"	"	"
4127	"	"	"	"	"	"	"
4128	"	"	"	"	"	"	"
4129	"	"	"	"	"	"	"
4130	"	"	"	"	"	"	"
4131	"	"	"	"	"	"	"
4132	"	"	"	"	"	"	"
4133	"	"	"	"	"	"	"
4134	"	"	"	"	"	"	"
4135	"	"	"	"	"	"	"
4136	"	"	"	"	"	"	"
4137	"	"	"	"	"	"	"
4138	"	"	"	"	"	"	"
4139	"	"	"	"	"	"	"
4140	"	"	"	"	"	"	"
4141	"	"	"	"	"	"	"
4142	"	"	"	"	"	"	"
4143	"	"	"	"	"	"	"
4144	"	"	"	"	"	"	"
4145	"	"	"	"	"	"	"
4146	"	"	"	"	"	"	"
4147	"	"	"	"	"	"	"
4148	"	"	"	"	"	"	"
4149	"	"	"	"	"	"	"
4150	"	"	"	"	"	"	"
4151	"	"	"	"	"	"	"
4152	"	"	"	"	"	"	"
4153	"	"	"	"	"	"	"
4154	"	"	"	"	"	"	"
4155	"	"	"	"	"	"	"
4156	"	"	"	"	"	"	"
4157	"	"	"	"	"	"	"
4158	"	"	"	"	"	"	"
4159	"	"	"	"	"	"	"

TASK 1E - EXHIBIT 2
SIGNAL CORPS CONTRACT

Vibration Test

Start Date_____
Completion Date_____

Type 2N914

Unit No.	20-2000-20 Cycle Time	Period I 3 Hrs	Period II 3 Hrs	Period III 6 Hrs	Period IV 12 Hrs	Period V 24 Hrs	Period VI 48 Hrs
4160	10 Min.	Unit Good	Unit Good	Unit Good	Unit Good	Unit Good	Unit Good
4161	"	"	"	"	"	"	"
4162	"	"	"	"	"	"	"
4163	"	"	"	"	"	"	"
4164	"	"	"	"	"	"	"
4165	"	"	"	"	"	"	"
4166	"	"	"	"	"	"	"
4167	"	"	"	"	"	"	"
4168	"	"	"	"	"	"	"
4169	"	"	"	"	"	"	"
4170	"	"	"	"	"	"	"
4171	"	"	"	"	"	"	"
4172	"	"	"	"	"	"	"
4173	"	"	"	"	"	"	"
4174	"	"	"	"	"	"	"
4175	"	"	"	"	"	"	"
4176	"	"	"	"	"	"	"
4177	"	"	"	"	"	"	"
4178	"	"	"	"	"	"	"
4179	"	"	"	"	"	"	"
4180	"	"	"	"	"	"	"
4181	"	"	"	"	"	"	"
4182	"	"	"	"	"	"	"
4183	"	"	"	"	"	"	"
4184	"	"	"	"	"	"	"
4185	"	"	"	"	"	"	"
4186	"	"	"	"	"	"	"
4187	"	"	"	"	"	"	"
4188	"	"	"	"	"	"	"
4189	"	"	"	"	"	"	"
4190	"	"	"	"	"	"	"
4191	"	"	"	"	"	"	"
4192	"	"	"	"	"	"	"
4193	"	"	"	"	"	"	"
4194	"	"	"	"	"	"	"
4195	"	"	"	"	"	"	"
4196	"	"	"	"	"	"	"
4197	"	"	"	"	"	"	"
4198	"	"	"	"	"	"	"
4199	"	"	"	"	"	"	"
4200	"	"	"	"	"	"	"
4201	"	"	"	"	"	"	"
4202	"	"	"	"	"	"	"
4203	"	"	"	"	"	"	"
4204	"	"	"	"	"	"	"
4205	"	"	"	"	"	"	"
4206	"	"	"	"	"	"	"
4207	"	"	"	"	"	"	"
4208	"	"	"	"	"	"	"
4209	"	"	"	"	"	"	"
4210	"	"	"	"	"	"	"
4211	"	"	"	"	"	"	"
4212	"	"	"	"	"	"	"

TASK 1E - EXHIBIT 2
SIGNAL CORPS CONTRACT

Start Date_____
Completion Date_____

Vibration Test

Type 2N914

Unit No.	20-2000-20 Cycle Time	Period I 3 Hrs	Period II 3 Hrs	Period III 6 Hrs	Period IV 12 Hrs	Period V 24 Hrs	Period V 48 Hrs
4213	10 Min.	Unit Good	Unit Good	Unit Good	Unit Good	Unit Good	Unit Good
4214	"	"	"	"	"	"	"
4215	"	"	"	"	"	"	"
4216	"	"	"	"	"	"	"
4217	"	"	"	"	"	"	"
4218	"	"	"	"	"	"	"
4219	"	"	"	"	"	"	"
4220	"	"	"	"	"	"	"
4221	"	"	"	"	"	"	"
4222	"	"	"	"	"	"	"
4223	"	"	"	"	"	"	"
4224	"	"	"	"	"	"	"
4225	"	"	"	"	"	"	"
4226	"	"	"	"	"	"	"
4227	"	"	"	"	"	"	"
4228	"	"	"	"	"	"	"
4229	"	"	"	"	"	"	"
4230	"	"	"	"	"	"	"
4231	"	"	"	"	"	"	"
4232	"	"	"	"	"	"	"
4233	"	"	"	"	"	"	"
4234	"	"	"	"	"	"	"
4235	"	"	"	"	"	"	"
4236	"	"	"	"	"	"	"
4237	"	"	"	"	"	"	"
4238	"	"	"	"	"	"	"
4239	"	"	"	"	"	"	"
4240	"	"	"	"	"	"	"
4241	"	"	"	"	"	"	"
4242	"	"	"	"	"	"	"
4243	"	"	"	"	"	"	"
4244	"	"	"	"	"	"	"
4245	"	"	"	"	"	"	"
4246	"	"	"	"	"	"	"
4247	"	"	"	"	"	"	"
4248	"	"	"	"	"	"	"
4249	"	"	"	"	"	"	"
4250	"	"	"	"	"	"	"
4251	"	"	"	"	"	"	"
4252	"	"	"	"	"	"	"
4253	"	"	"	"	"	"	"
4254	"	"	"	"	"	"	"
4255	"	"	"	"	"	"	"
4256	"	"	"	"	"	"	"
4257	"	"	"	"	"	"	"
4258	"	"	"	"	"	"	"
4259	"	"	"	"	"	"	"
4260	"	"	"	"	"	"	"
4261	"	"	"	"	"	"	"
4262	"	"	"	"	"	"	"
4263	"	"	"	"	"	"	"
4264	"	"	"	"	"	"	"
4265	"	"	"	"	"	"	"

TASK 1E - EXHIBIT 2
SIGNAL CORPS CONTRACT

Start Date_____
Completion Date_____

Vibration Test

Type 2N194

Unit No.	20-2000-20 Cycle Time	Period I 3 Hrs	Period II 3 Hrs	Period III 6 Hrs	Period IV 12 Hrs	Period V 24 Hrs	Period VI 48 Hrs
4266	10 Min	Unit Good	Unit Good	Unit Good	Unit Good	Unit Good	Unit Good
4267	"	"	"	"	"	"	"
4268	"	"	"	"	"	"	"
4269	"	"	"	"	"	"	"
4270	"	"	"	"	"	"	"
4271	"	"	"	"	"	"	"
4272	"	"	"	"	"	"	"
4273	"	"	"	"	"	"	"
4274	"	"	"	"	"	"	"
4275	"	"	"	"	"	"	"
4276	"	"	"	"	"	"	"
4277	"	"	"	"	"	"	"
4278	"	"	"	"	"	"	"
4279	"	"	"	"	"	"	"
4280	"	"	"	"	"	"	"
4281	"	"	"	"	"	"	"
4282	"	"	"	"	"	"	"
4283	"	"	"	"	"	"	"
4284	"	"	"	"	"	"	"
4285	"	"	"	"	"	"	"
4286	"	"	"	"	"	"	"
4287	"	"	"	"	"	"	"
4288	"	"	"	"	"	"	"
4289	"	"	"	"	"	"	"
4290	"	"	"	"	"	"	"
4291	"	"	"	"	"	"	"
4292	"	"	"	"	"	"	"
4293	"	"	"	"	"	"	"
4294	"	"	"	"	"	"	"
4295	"	"	"	"	"	"	"
4296	"	"	"	"	"	"	"
4297	"	"	"	"	"	"	"
4298	"	"	"	"	"	"	"
4299	"	"	"	"	"	"	"
4300	"	"	"	"	"	"	"
4301	"	"	"	"	"	"	"
4302	"	"	"	"	"	"	"
4303	"	"	"	"	"	"	"
4304	"	"	"	"	"	"	"
4305	"	"	"	"	"	"	"
4306	"	"	"	"	"	"	"
4307	"	"	"	"	"	"	"
4308	"	"	"	"	"	"	"
4309	"	"	"	"	"	"	"
4310	"	"	"	"	"	"	"
4311	"	"	"	"	"	"	"
4312	"	"	"	"	"	"	"
4313	"	"	"	"	"	"	"
4314	"	"	"	"	"	"	"
4315	"	"	"	"	"	"	"
4316	"	"	"	"	"	"	"
4317	"	"	"	"	"	"	"
4318	"	"	"	"	"	"	"

TASK 1E - EXHIBIT 2
SIGNAL CORPS CONTRACT

Start Date _____
Completion Date _____

Vibration Test

Type 2N914

Unit No.	20-2000-20 Cycle Time	Period I 3 Hrs	Period II 3 Hrs	Period III 6 Hrs	Period IV 12 Hrs	Period V 24 Hrs	Period VI 48 Hrs
4319	10 Min.	Unit Good	Unit Good	Unit Good	Unit Good	Unit Good	Unit Good
4320	"	"	"	"	"	"	"
4321	"	"	"	"	"	"	"
4322	"	"	"	"	"	"	"
4323	"	"	"	"	"	"	"
4324	"	"	"	"	"	"	"
4325	"	"	"	"	"	"	"
4326	"	"	"	"	"	"	"
4327	"	"	"	"	"	"	"
4328	"	"	"	"	"	"	"
4329	"	"	"	"	"	"	"
4330	"	"	"	"	"	"	"
4331	"	"	"	"	"	"	"
4332	"	"	"	"	"	"	"
4333	"	"	"	"	"	"	"
4334	"	"	"	"	"	"	"
4335	"	"	"	"	"	"	"
4336	"	"	"	"	"	"	"
4337	"	"	"	"	"	"	"
4338	"	"	"	"	"	"	"
4339	"	"	"	"	"	"	"
4340	"	"	"	"	"	"	"
4341	"	"	"	"	"	"	"
4342	"	"	"	"	"	"	"
4343	"	"	"	"	"	"	"
4344	"	"	"	"	"	"	"
4345	"	"	"	"	"	"	"
4346	"	"	"	"	"	"	"
4347	"	"	"	"	"	"	"
4348	"	"	"	"	"	"	"
4349	"	"	"	"	"	"	"
4350	"	"	"	"	"	"	"
4351	"	"	"	"	"	"	"
4352	"	"	"	"	"	"	"
4353	"	"	"	"	"	"	"
4354	"	"	"	"	"	"	"
4355	"	"	"	"	"	"	"
4356	"	"	"	"	"	"	"
4357	"	"	"	"	"	"	"
4358	"	"	"	"	"	"	"
4359	"	"	"	"	"	"	"
4360	"	"	"	"	"	"	"
4361	"	"	"	"	"	"	"
4362	"	"	"	"	"	"	"
4363	"	"	"	"	"	"	"
4364	"	"	"	"	"	"	"
4365	"	"	"	"	"	"	"
4366	"	"	"	"	"	"	"
4367	"	"	"	"	"	"	"
4368	"	"	"	"	"	"	"
4369	"	"	"	"	"	"	"
4370	"	"	"	"	"	"	"
4371	"	"	"	"	"	"	"

TASK 1E - EXHIBIT 2
SIGNAL CORPS CONTRACT

Start Date_____
Completion Date_____

Vibration Test

Type 2N914

Unit No.	20-2000-20 Cycle Time	Period I 3 Hrs	Period II 3 Hrs	Period III 6 Hrs	Period IV 12 Hrs	Period V 24 Hrs	Period VI 48 Hrs
4319	10 Min.	Unit Good	Unit Good	Unit Good	Unit Good	Unit Good	Unit Good
4320	"	"	"	"	"	"	"
4321	"	"	"	"	"	"	"
4322	"	"	"	"	"	"	"
4323	"	"	"	"	"	"	"
4324	"	"	"	"	"	"	"
4325	"	"	"	"	"	"	"
4326	"	"	"	"	"	"	"
4327	"	"	"	"	"	"	"
4328	"	"	"	"	"	"	"
4329	"	"	"	"	"	"	"
4330	"	"	"	"	"	"	"
4331	"	"	"	"	"	"	"
4332	"	"	"	"	"	"	"
4333	"	"	"	"	"	"	"
4334	"	"	"	"	"	"	"
4335	"	"	"	"	"	"	"
4336	"	"	"	"	"	"	"
4337	"	"	"	"	"	"	"
4338	"	"	"	"	"	"	"
4339	"	"	"	"	"	"	"
4340	"	"	"	"	"	"	"
4341	"	"	"	"	"	"	"
4342	"	"	"	"	"	"	"
4343	"	"	"	"	"	"	"
4344	"	"	"	"	"	"	"
4345	"	"	"	"	"	"	"
4346	"	"	"	"	"	"	"
4347	"	"	"	"	"	"	"
4348	"	"	"	"	"	"	"
4349	"	"	"	"	"	"	"
4350	"	"	"	"	"	"	"
4351	"	"	"	"	"	"	"
4352	"	"	"	"	"	"	"
4353	"	"	"	"	"	"	"
4354	"	"	"	"	"	"	"
4355	"	"	"	"	"	"	"
4356	"	"	"	"	"	"	"
4357	"	"	"	"	"	"	"
4358	"	"	"	"	"	"	"
4359	"	"	"	"	"	"	"
4360	"	"	"	"	"	"	"
4361	"	"	"	"	"	"	"
4362	"	"	"	"	"	"	"
4363	"	"	"	"	"	"	"
4364	"	"	"	"	"	"	"
4365	"	"	"	"	"	"	"
4366	"	"	"	"	"	"	"
4367	"	"	"	"	"	"	"
4368	"	"	"	"	"	"	"
4369	"	"	"	"	"	"	"
4370	"	"	"	"	"	"	"
4371	"	"	"	"	"	"	"

TASK 1E - EXHIBIT 2
SIGNAL CORPS CONTRACT

Start Date_____
Completion Date_____

Vibration Test

Type 2N914

Unit No.	20-2000-20 Cycle Time	Period I 3 Hrs	Period II 3 Hrs	Period III 6 Hrs	Period IV 12 Hrs	Period V 24 Hrs	Period VI 48 Hrs
4319	10 Min.	Unit Good	Unit Good	Unit Good	Unit Good	Unit Good	Unit Good
4320	"	"	"	"	"	"	"
4321	"	"	"	"	"	"	"
4322	"	"	"	"	"	"	"
4323	"	"	"	"	"	"	"
4324	"	"	"	"	"	"	"
4325	"	"	"	"	"	"	"
4326	"	"	"	"	"	"	"
4327	"	"	"	"	"	"	"
4328	"	"	"	"	"	"	"
4329	"	"	"	"	"	"	"
4330	"	"	"	"	"	"	"
4331	"	"	"	"	"	"	"
4332	"	"	"	"	"	"	"
4333	"	"	"	"	"	"	"
4334	"	"	"	"	"	"	"
4335	"	"	"	"	"	"	"
4336	"	"	"	"	"	"	"
4337	"	"	"	"	"	"	"
4338	"	"	"	"	"	"	"
4339	"	"	"	"	"	"	"
4340	"	"	"	"	"	"	"
4341	"	"	"	"	"	"	"
4342	"	"	"	"	"	"	"
4343	"	"	"	"	"	"	"
4344	"	"	"	"	"	"	"
4345	"	"	"	"	"	"	"
4346	"	"	"	"	"	"	"
4347	"	"	"	"	"	"	"
4348	"	"	"	"	"	"	"
4349	"	"	"	"	"	"	"
4350	"	"	"	"	"	"	"
4351	"	"	"	"	"	"	"
4352	"	"	"	"	"	"	"
4353	"	"	"	"	"	"	"
4354	"	"	"	"	"	"	"
4355	"	"	"	"	"	"	"
4356	"	"	"	"	"	"	"
4357	"	"	"	"	"	"	"
4358	"	"	"	"	"	"	"
4359	"	"	"	"	"	"	"
4360	"	"	"	"	"	"	"
4361	"	"	"	"	"	"	"
4362	"	"	"	"	"	"	"
4363	"	"	"	"	"	"	"
4364	"	"	"	"	"	"	"
4365	"	"	"	"	"	"	"
4366	"	"	"	"	"	"	"
4367	"	"	"	"	"	"	"
4368	"	"	"	"	"	"	"
4369	"	"	"	"	"	"	"
4370	"	"	"	"	"	"	"
4371	"	"	"	"	"	"	"

TASK 1E - EXHIBIT 2
SIGNAL CORPS CONTRACT

Start Date_____
Completion Date_____

Vibration Test

Type 2N914

Unit No.	20-2000-20 Cycle Time	Period I 3 Hrs	Period II 3 Hrs	Period III 6 Hrs	Period IV 12 Hrs	Period V 24 Hrs	Period VI 48 Hrs
4372	10 Min.	Unit Good	Unit Good	Unit Good	Unit Good	Unit Good	Unit Good
4373	"	"	"	"	"	"	"
4374	"	"	"	"	"	"	"
4375	"	"	"	"	"	"	"
4376	"	"	"	"	"	"	"
4377	"	"	"	"	"	"	"
4378	"	"	"	"	"	"	"
4379	"	"	"	"	"	"	"
4380	"	"	"	"	"	"	"
4381	"	"	"	"	"	"	"
4382	"	"	"	"	"	"	"
4383	"	"	"	"	"	"	"
4384	"	"	"	"	"	"	"
4385	"	"	"	"	"	"	"
4386	"	"	"	"	"	"	"
4387	"	"	"	"	"	"	"
4388	"	"	"	"	"	"	"
4389	"	"	"	"	"	"	"
4390	"	"	"	"	"	"	"
4391	"	"	"	"	"	"	"
4392	"	"	"	"	"	"	"
4393	"	"	"	"	"	"	"
4394	"	"	"	"	"	"	"
4395	"	"	"	"	"	"	"
4396	"	"	"	"	"	"	"
4397	"	"	"	"	"	"	"
4398	"	"	"	"	"	"	"
4399	"	"	"	"	"	"	"
4400	"	"	"	"	"	"	"
4401	"	"	"	"	"	"	"
4402	"	"	"	"	"	"	"
4403	"	"	"	"	"	"	"
4404	"	"	"	"	"	"	"
4405	"	"	"	"	"	"	"
4406	"	"	"	"	"	"	"
4407	"	"	"	"	"	"	"
4408	"	"	"	"	"	"	"
4409	"	"	"	"	"	"	"
4410	"	"	"	"	"	"	"
4411	"	"	"	"	"	"	"
4412	"	"	"	"	"	"	"
4413	"	"	"	"	"	"	"
4414	"	"	"	"	"	"	"
4415	"	"	"	"	"	"	"
4416	"	"	"	"	"	"	"
4417	"	"	"	"	"	"	"
4418	"	"	"	"	"	"	"
4419	"	"	"	"	"	"	"
4420	"	"	"	"	"	"	"
4421	"	"	"	"	"	"	"
4422	"	"	"	"	"	"	"
4423	"	"	"	"	"	"	"
4424	"	"	"	"	"	"	"

TASK 1E - EXHIBIT 2
SIGNAL CORPS CONTRACT

Start Date_____
Completion Date_____

Vibration Test

Type 2N914

Unit No.	20-2000-20 Cycle Time	Period I 3 Hrs	Period II 3 Hrs	Period III 6 Hrs	Period IV 12 Hrs	Period V 24 Hrs	Period VI 48 Hrs
4425	10 Min.	Unit Good	Unit Good	Unit Good	Unit Good	Unit Good	Unit Good
4426	"	"	"	"	"	"	"
4427	"	"	"	"	"	"	"
4428	"	"	"	"	"	"	"
4429	"	"	"	"	"	"	"
4430	"	"	"	"	"	"	"
4431	"	"	"	"	"	"	"
4432	"	"	"	"	"	"	"
4433	"	"	"	"	"	"	"
4434	"	"	"	"	"	"	"
4435	"	"	"	"	"	"	"
4436	"	"	"	"	"	"	"
4437	"	"	"	"	"	"	"
4438	"	"	"	"	"	"	"
4439	"	"	"	"	"	"	"
4440	"	"	"	"	"	"	"
4441	"	"	"	"	"	"	"
4442	"	"	"	"	"	"	"
4443	"	"	"	"	"	"	"
4444	"	"	"	"	"	"	"
4445	"	"	"	"	"	"	"
4446	"	"	"	"	"	"	"
4447	"	"	"	"	"	"	"
4448	"	"	"	"	"	"	"
4449	"	"	"	"	"	"	"
4450	"	"	"	"	"	"	"
4451	"	"	"	"	"	"	"
4452	"	"	"	"	"	"	"
4453	"	"	"	"	"	"	"
4454	"	"	"	"	"	"	"
4455	"	"	"	"	"	"	"
4456	"	"	"	"	"	"	"
4457	"	"	"	"	"	"	"
4458	"	"	"	"	"	"	"
4459	"	"	"	"	"	"	"
4460	"	"	"	"	"	"	"
4461	"	"	"	"	"	"	"
4462	"	"	"	"	"	"	"
4463	"	"	"	"	"	"	"
4464	"	"	"	"	"	"	"
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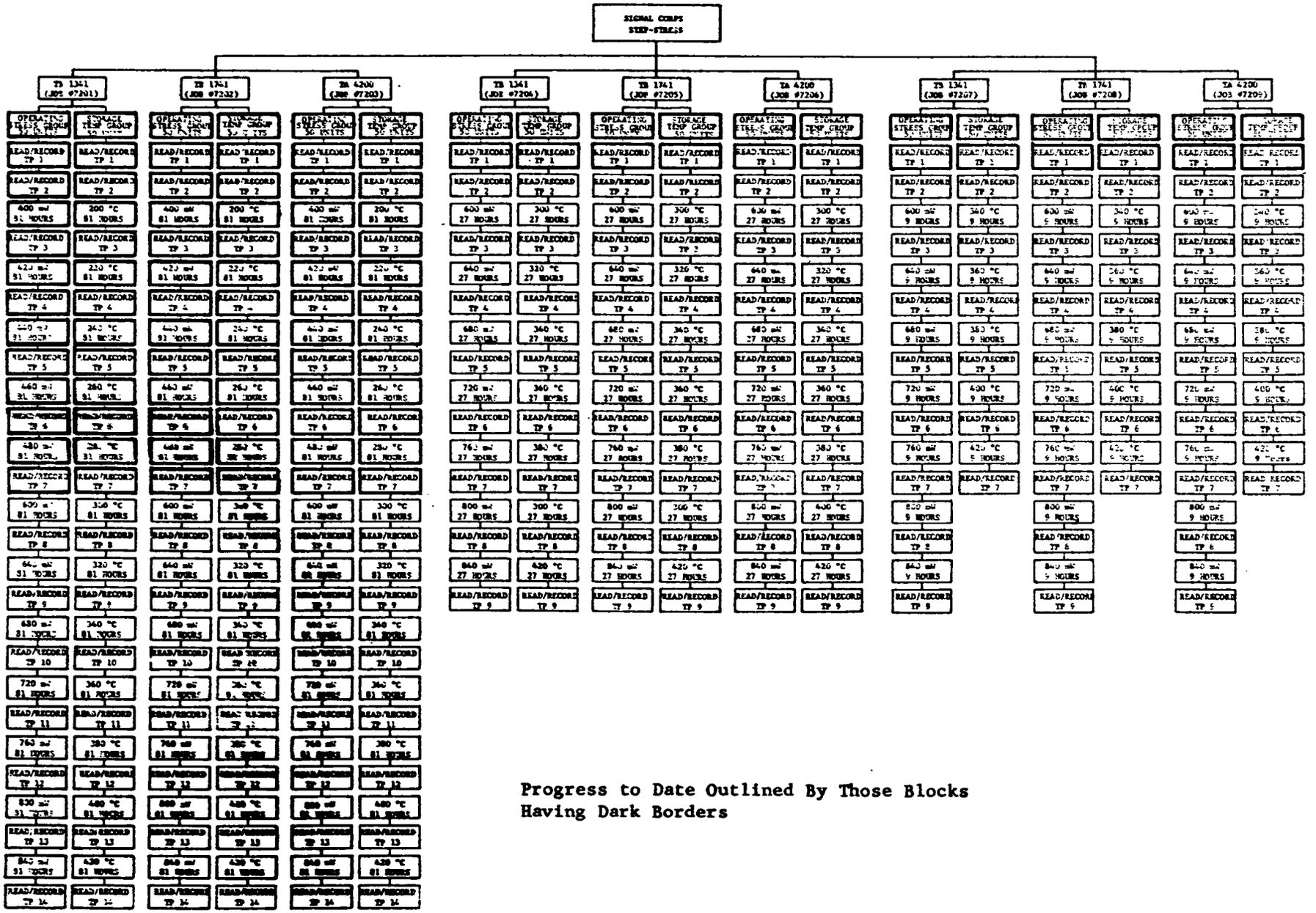
4467	"	"	"	"	"	"	"
4468	"	"	"	"	"	"	"
4469	"	"	"	"	"	"	"
4470	"	"	"	"	"	"	"
4471	"	"	"	"	"	"	"
4472	"	"	"	"	"	"	"
4473	"	"	"	"	"	"	"
4474	"	"	"	"	"	"	"
4475	"	"	"	"	"	"	"
4476	"	"	"	"	"	"	"
4477	"	"	"	"	"	"	"

TASK 1E - EXHIBIT 3
STEP-STRESS PROGRAM OUTLINE



Progress to Date Outlined By Those Blocks
Having Dark Borders

SECTION III

TASK 2 - PREPARATION OF SUBSTRATE FOR EPITAXIAL GROWTH

CONTENTS

SECTION III

TASK 2 - PREPARATION OF SUBSTRATE FOR EPITAXIAL GROWTH

J. M. Schroeder

PURPOSE

In order to obtain the highest degree of integrity in epitaxial material for transistor fabrication, the substrate material and the surface upon which the epitaxial silicon is grown must be of the highest integrity. To accomplish this goal a three step process is proposed whereby:

1. The single crystaline silicon ingot is sawed solely by electrochemical methods.
2. The slices are polished to a damage free, undistorted mirror surface by mechanical-chemical methods.
3. The wafers are etched in the epitaxial reactor prior to deposition to insure removal of foreign material from the wafer surface.

BACKGROUND

Prior to the second quarter, experimental work was done in the three areas proposed, namely sawing, polishing and etching in the reactor.

Saw experiments involved the evaluation of a multi-blade wafering machine that cuts with an abrasive and reciprocating blades to minimize crystal damage instead of one high speed diamond wheel.

Wafer polishing techniques were worked out using a mechanical-chemical method. Design and fabrication work was started on an experimental machine that might do this polishing as a production method.

Experiments were designed and made to determine a method of etching polished wafers while enclosed in an epitaxial reactor. Various parameters were explored so that the most advantageous conditions might be selected.

PROGRESS DURING THIS PERIOD

Step 1 - Sawing of Silicon Slices

The work on crystal sawing involved the evaluation with regard to depth of damage of slices sawed with the Norton multi-blade wafering machine. Rough determinations were made to determine this depth using preferential etches to reveal saw damage at a given depth. The damage to the crystal was found to be less as compared to slices sawed with a high speed diamond wheel, but exact comparisons are difficult because of the variables involved in the methods of damage determination.

Attention was focused on an investigation of the feasibility of electrolitic sawing of silicon whereby the damage to the crystal could be virtually zero.

Simple experiments were performed by biasing a silicon ingot positive and a thin metal blade negative (See exhibit 1). A current was established between blade and crystal through an electrolite of deionized water by rubbing the blade over the crystal. It was found that silicon could be removed by this method as a function of current density and friction. A single slice was cut by this method. The cut made by the blade was straight with virtually no side erosion and removed silicon only where the blade was in contact with the silicon (See exhibit 2). To further evaluate this principle, the multi-blade saw was equipped with brushes and biasing terminals. Two problems were readily apparent:

1. With deionized water as an electrolite a very high current density must be maintained requiring a large power supply to accommodate the three hundred blades.
2. If electrolitic additives are used to reduce current needed, the additives must be non-corrosive so that the saw will not be attacked.

If these problems can be eliminated, silicon slices might be sawed while maintaining the integrity of the grown crystal.

CONCLUSIONS

The conclusions derived from the saw experiment were as follows:

1. All silicon slices sawed with the high speed diamond wheel have damage inflicted into the crystal 40 to 80 microns beneath the surface.
2. Slices sawed with six micron abrasive and the multiblade saw are damaged 20 to 60 microns beneath the surface.
3. Slices sawed by electrochemical methods are apparently not damaged due to mechanical action.
4. Slices might be sawed by electrochemical techniques utilizing the multi-blade saw if an electrolitic solution can be found that will limit current necessary for cutting action and will not corrode the machine.
5. Slices cut by this method will retain their dislocation integrity in the slice form.
6. Material savings can be realized by cutting thinner wafers and likewise more slices can be obtained per inch of crystal.

Step 2 - Mechanical-Chemical Polishing of Silicon Slices

Over four thousand silicon wafers were mechanically-chemically polished. The process gives extremely planar, mirror like surfaces. Damage to the crystal can be attributed only to air-borne particles falling into the machine and saw chips from the wafers scratching other wafers. A 60% yield can be

realized with the polishing machine as it is in pilot operation. It should be noted that this process begins with sawed slices and takes them directly to the condition "prior to epitaxial deposition". This eliminates rigorous, mounting, lapping, cleaning, etching, and gauging operations that are normally used. The machine currently in use can polish 48 slices per hour (See exhibit 3). One operator could operate two and possibly three of these machines at once. The machine after being used for three months is in operating condition with no major repairs or modifications having been necessitated.

CONCLUSIONS

Conclusions to be gathered from the work on the polishing project are as follows:

1. The latest model mechanical-chemical polishing machine is operational and capable of producing 60% of 48 slices per hour.
2. The process eliminates many of the steps from mounting and lapping to etching and gauging.
3. Airborne dust falling into the machine and saw chips on the slices are problems affecting yield.
4. To advance the process further a machine incorporating the experience gained in choice of design materials, wafer holding fixtures, acid handling methods, and overall convenience of operation of the machine should be designed and fabricated.
5. This machine would be the summation of all experience gained and would render a higher yield, lower cost process with complete emphasis on integrity of material.

Step 3 - Vapor Etching of Silicon Wafers in a Closed Reactor

The process dealing with vapor etching of silicon in a closed reactor, as outlined in the First Quarterly Report, has proven useful. A marked improvement in epitaxial film surface has been noted. Hillocks believed to be nucleated by foreign particles on the surface of the silicon wafer are not present when this method of etching is used, so that virtually no hillocks are formed as the film progresses. The process is in pilot production and is being evaluated for electrical parameters and surface improvement. One additional advantage in this process was found. The epitaxial growth reaction can be balanced by the utilization of HCl additions. From the balanced conditions much can be learned about the rate of reaction and quantities of reaction constituents needed. From this information more process stabilization and regulation can be realized from the growth process itself.

CONCLUSIONS

Conclusions derived from experiments dealing with etching of silicon in a closed reactor are as follows:

1. The addition of a quantity of HCl gas to the growth constituents drives the reaction in reverse so that non-preferential etching may take place.
2. This reaction can take place inside the reactor immediately prior to epitaxial deposition.
3. Surface and electrical improvements can be realized from this process.
4. Information about the growth reaction can be gained from the utilization of this process.

PROGRAM FOR NEXT INTERVAL

Step 1 - Sawing of Silicon Slices

Experiments will be conducted with different electrolites to establish a process for electrolitic cutting of silicon. Modifications will be made to the multi-blade saw to accommodate this process.

Step 2 - Mechanical-Chemical Polishing of Silicon Slices

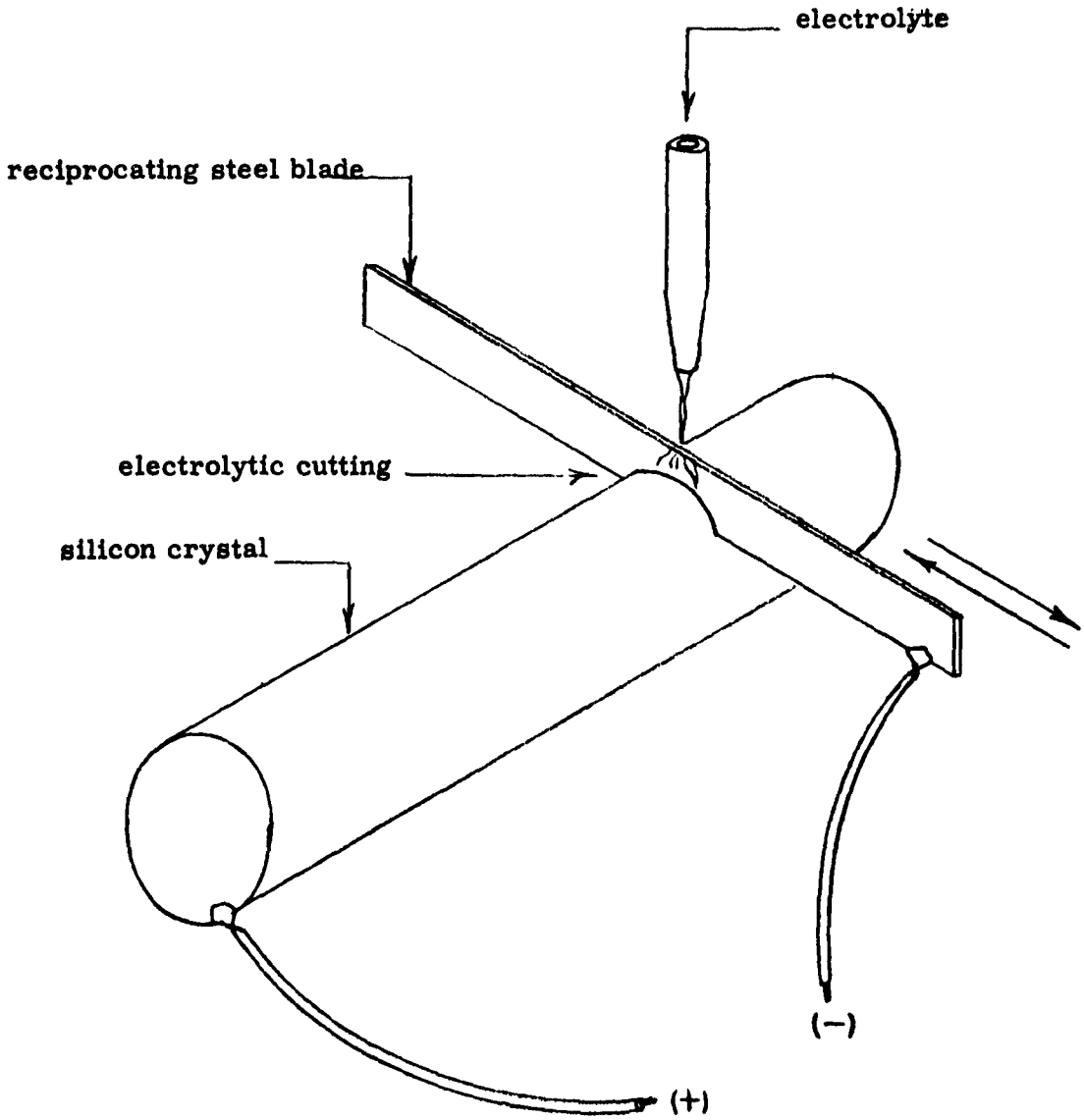
As advanced mechanical-chemical polishing machine will be designed and built to incorporate information gained from prior experiments and operation. The machine will be placed in operation before the end of this quarter for evaluation and modification.

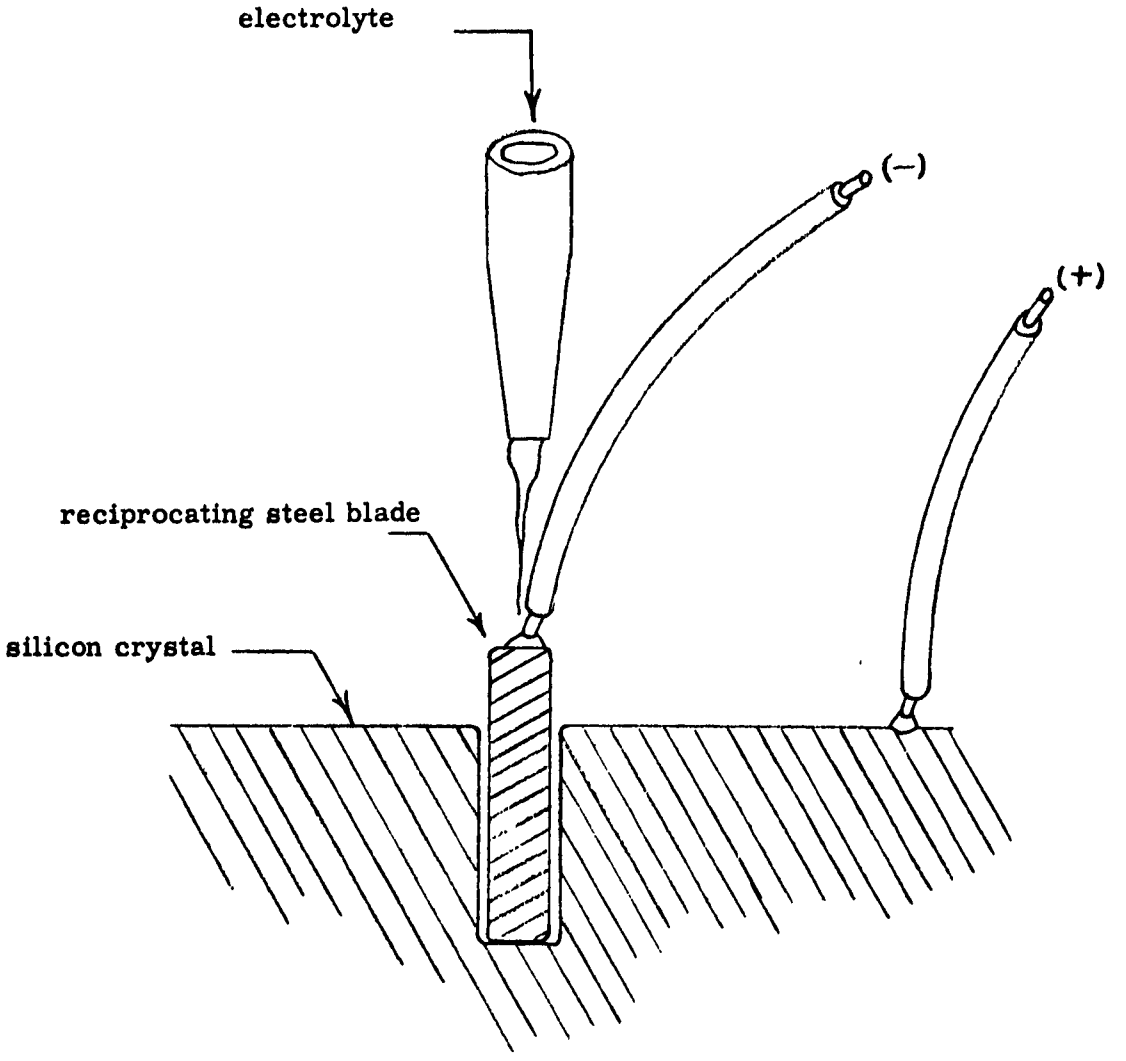
Step 3 - Vapor Etching of Silicon Wafers in a Closed Reactor

Experiments and evaluation of vapor etching in a closed epitaxial reactor will continue until such time as the complete process might be integrated into the form of electrochemically sawed slices from the multi-blade saw, mechanical-chemical polished on the advanced machine and vapor etched in a closed epitaxial reactor.

TASK 2 - EXHIBIT 1

SKETCH OF ELECTROLYTIC SLICING EXPERIMENT



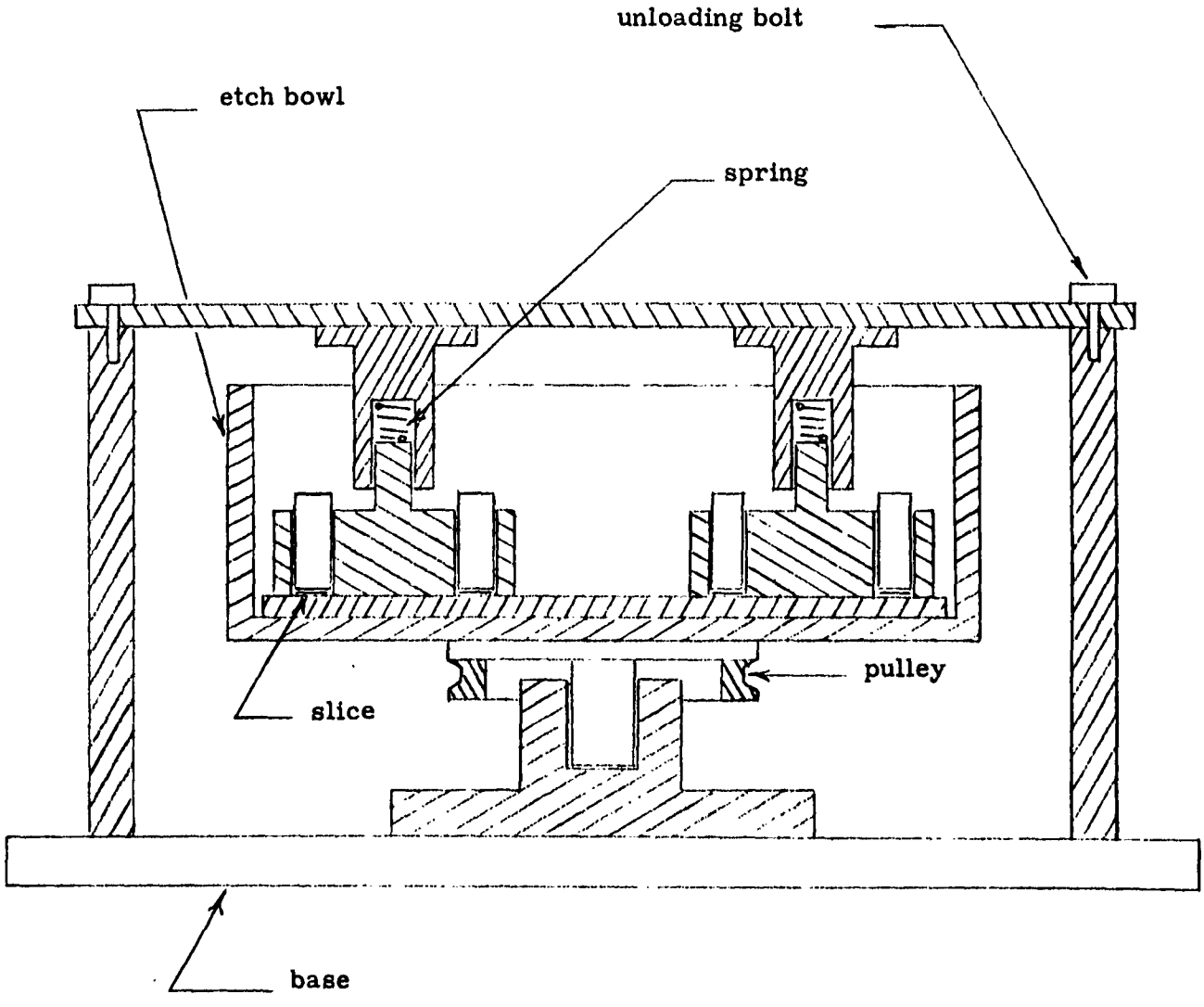


SIDE VIEW SKETCH OF ELECTROLYTIC SLICING BLADE
SHOWING CURRENT BIASING AND GEOMETRY OF CUT

TASK 2 - EXHIBIT 2

TASK 2 - EXHIBIT 3

SKETCH OF PILOT MECHANICAL - CHEMICAL POLISHING MACHINE



SECTION III

TASK 3 - IMPROVE HEADER PLATING

CONTENTS

SECTION III

TASK 3 - IMPROVE HEADER PLATING

P. Rollason

PURPOSE

Continuing our effort to provide Fairchild Semiconductor with a gold plated header that is equally suitable for NPN and PNP devices, trial and evaluation #1, and trial and evaluation #2 have been completed. The results and documentation on these two runs will be described and conclusions will be drawn from the information obtained.

BACKGROUND

Prior to the second quarter, a method was developed which showed promise of providing the expected benefits. The necessary gold bath and auxiliary equipment were installed in the plating shop. Plating samples were evaluated and the plating process that showed most promise was used to provide units used in trial and evaluation #1 and #2.

PROGRESS TO DATE

Evaluation #1

The plated units were accepted for production and Special Tests #592A and 592B were originated on 7-17-62. They were completed 8-8-62.

The documentation includes:

a. Package Evaluation Log Sheets (Submitted with 1st quarterly report)

b. Special Test Forms #592A and B (Exhibits 1 and 2)

c. Production Classification Test Cards for Tests #592A and B) (Exhibits 3 & 4)

d. A summary of the information obtained on these units during Evaluation #1 (Exhibit 5)

Conclusions drawn from Evaluation #1 (Special Test #592A and B)

1. The standard plated units checked performed far better than expected on the ISW (150°C) test.

2. A discrepancy existed between the production line ISW (150°C) test results and those obtained by read out scope when rechecked in Applications Engineering. Units in following tests will only be checked in ISW (150°C) on a scope in Applications.

3. Since the expected difference in ISW (150°C) reject level on the two types of plating did not occur due to the unforseen improvement in the standard plate, further evidence in the form of Evaluation #2 is awaited before further conclusions can be drawn.

Evaluation #2

The plated units to be used for Evaluation #2 were accepted for production and Special tests #SC2A and SC2B were initiated on 9-17-62 and completed 10-22-62.

Documentation for Evaluation #2 includes:

a. Package Evaluation Log Sheets (Exhibits 6 and 7)

b. Special Test Forms #SC-2-A, and #SC-2-B (Exhibits 8 and 9)

c. Production Classification Test Cards for Tests SC-2-A and B (Exhibits 10 and 11)

d. Summary of information obtained during evaluation #2 (Exhibit 12)

Conclusions drawn from Evaluation #2.

1. The unexpected improvement in the Standard Plating continued as far as ISW (150°C) is concerned.

2. The improvement in the Standard Plate must be investigated since if it continues during Evaluation #3 and #4 it renders invalid the present system of detecting improvements in plating. If the Standard Plate can be controlled, it promises plating of high quality which can be applied more economically than the special or duplex plate.

3. Since the expected benefits of the special plate rely on the removal of the effect of the Kovar structure on the plate, it is possible that the performance of the standard gold can be related to a factor such as headers composed of fine structured Kovar. All

"A"

TASK 3 - EXHIBIT 1

DP No. 1
Appx. 1

FAIRCHILD SEMICONDUCTOR CORPORATION

Special Test
No. 592A

Originator J. S. Horton Date 7-17-62

Approved _____ Date 7-16-62 Approved _____ Date 19 Jul 62
(Originator's Dept) (Product Manager)

FT-TYPE TA-4500 Unit Identification _____
(Run No., etc)

Starting Date _____

Originator _____
(Initials)

Die Sort Target Date _____

Prod. Mgr. _____
(Initials)

Classification Target Date _____

Contact originator as indicated on attached Routing Check-off List. Do not hold material at any point not checked.

PURPOSE OF THIS TEST: To evaluate standard Fairchild plating on Signal Corp. Project. As control for special plating. (Sample A)

INSTRUCTIONS: (Be specific - Attach separate Flow Chart, if necessary)
Die attach 150 TO-5 headers (Standard Plating).

1. Use 4500 dice, normal Process through classification.
2. Maintain header batch identity.
3. Save all rejects as indicated below.
   - a. Die Attach
   - b. Lead Weld
   - c. Classification

Use cost No. - 11-9010-000 for WIP, etc. Test time used.

CONCLUSIONS & RECOMMENDATIONS: (Attach separate report, if necessary)

Originator to recap desired information (emitter diffusion results, die sort results, DA, LB, LW results, etc) on reverse side.

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B

TASK 3 - EXHIBIT 2

DP No. 1
Appx. 1

FAIRCHILD SEMICONDUCTOR CORPORATION

Special Test
No. 592 B

Originator J. S. Horton Date 7-17-62

Approved _____ Date 7-16-62 Approved _____ Date 19 Jul 62
(Originator's Dept) (Product Manager)

FT-TYPE TA-4500 Unit Identification _____
(Run No., etc)

Starting Date _____

Originator _____
(Initials)

Die Sort Target Date _____

Prod. Mgr. _____
(Initials)

Classification Target Date _____

Contact originator as indicated on attached Routing Check-off List. Do not hold material at any point not checked.

PURPOSE OF THIS TEST: To evaluate special gold plating on Signal Corp. Project.
(S. # B)

INSTRUCTIONS: (Be specific - Attach separate Flow Chart, if necessary)

Die attach 150 special plated TO-5 headers.

(1) Use 4500 dice, normal process through classification.

(2) Maintain header batch identity.

(3) Save all rejects as indicated below.

(a.) Die Attach

(b.) Lead Weld

c. Classification

Use cost No. — 11-9010-0000 [illegible]

CONCLUSIONS & RECOMMENDATIONS: (Attach separate report, if necessary)

Dice [illegible] — [illegible] (Signal Corp) to come from same lot

Originator to recap desired information (emitter diffusion results, die sort results, DA, LB, LW results, etc) on reverse side.

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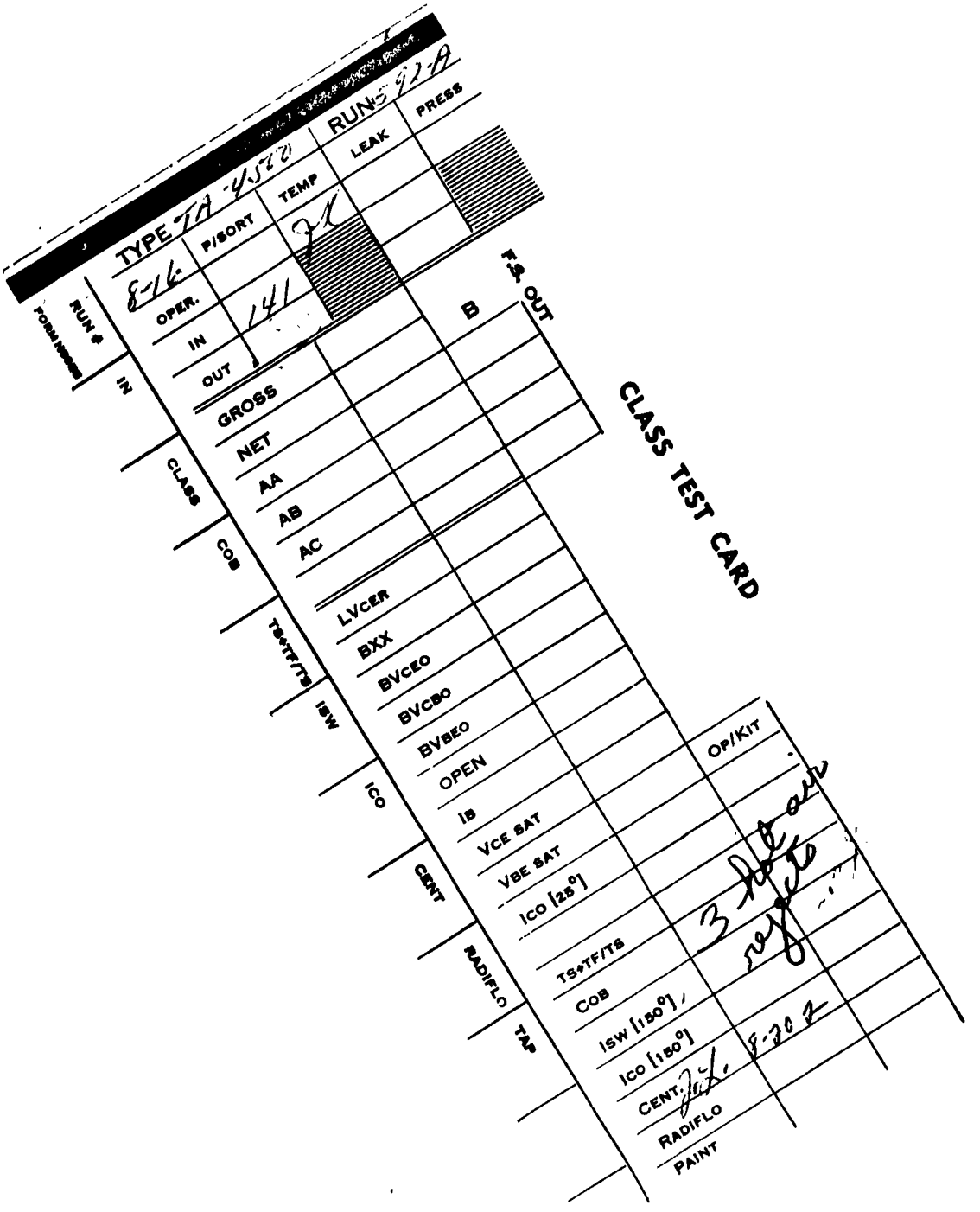
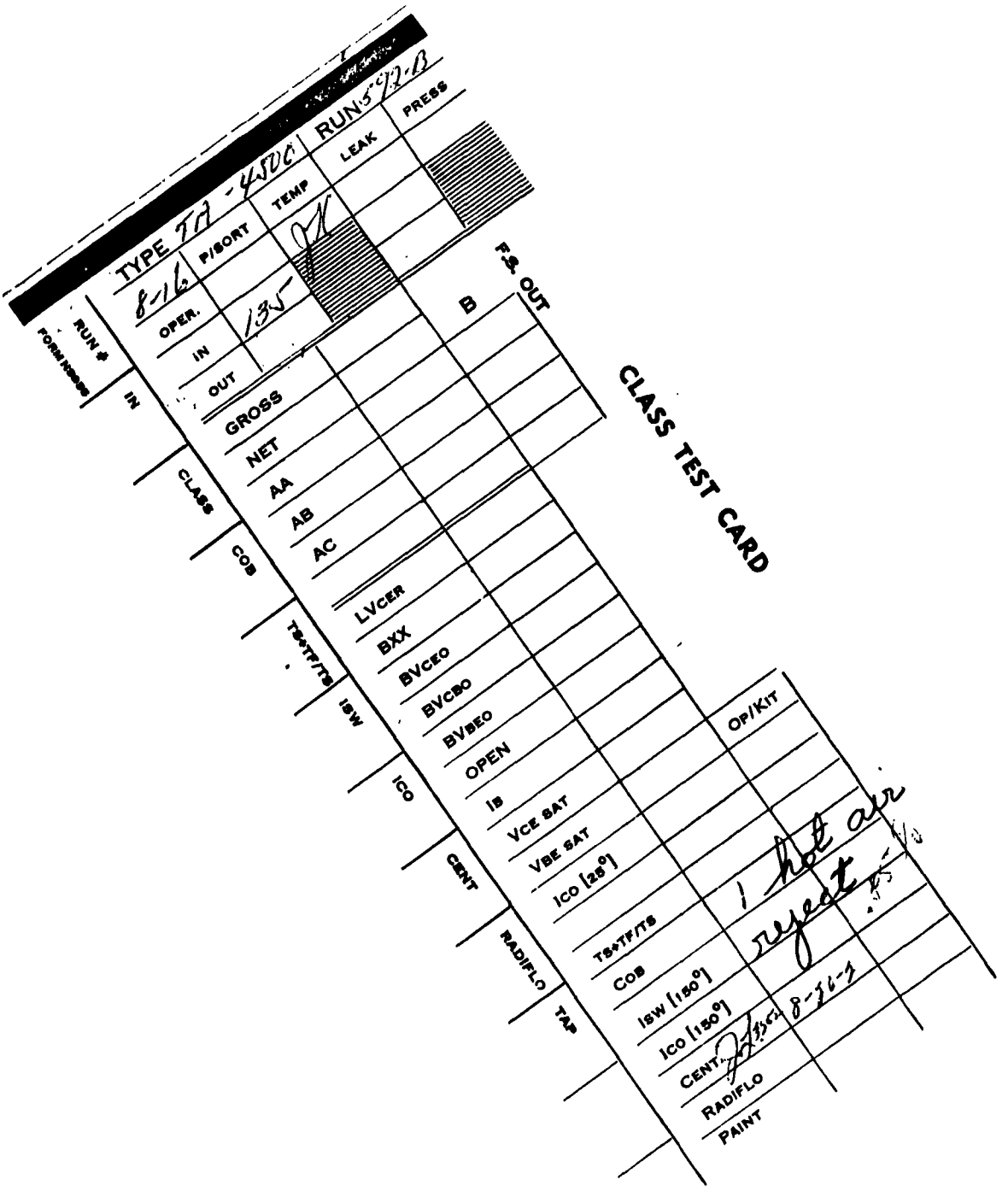
TASK 3 - EXHIBIT 3

PRODUCTION CLASSIFICATION TEST CARD - #592A



PRODUCTION CLASSIFICATION TEST CARD - #592B



TASK 3 - EXHIBIT 5

9-4-62

TO: H. Roos

FROM: J. S. Horton

SUBJECT: Signal Corp. Plating Project.

CC. N. Peterson
P. Rollason

First batch of TO-5 headers plated for Signal Corp. Project were evaluated by Packaging Group 7-16-62 and Special tests written and approved 7-19-62. Special tests were delayed until 8-2-62. Units were processed through final seal by Process Development line and classified by Production. Results were as shown below.

1st Run Signal Corp. Plating Project

	Standard Plating	Duplex Plating
Run Number	592-A	592-B
No. Units Per Run	150	150
Type	P.N.P. dice - Split lot of 300	
Die Attach	Good	Good
Lead Bond	Good	Good
Lead Weld	Good	Good
% Yield at Classification	89.5	86.7
Vce Sat (Fall out)	0	0
Isw (150°) Prod. Equip. (Fall out)	2.4%	0.85%
Isw (150°) Read out on Scope (Fall out)	2.4%	5.99%
Solderability	Fair to Good	Fair

Test units shall be returned to P. Rollason for retaining until completion of Project.

J. S. Horton
Packaging Evaluation

TASK 3 - EXHIBIT 5

9-4-62

TO: H. Roos

FROM: J. S. Horton

SUBJECT: Signal Corp. Plating Project.

CC. N. Peterson
P. Rollason

First batch of TO-5 headers plated for Signal Corp. Project were evaluated by Packaging Group 7-16-62 and Special tests written and approved 7-19-62. Special tests were delayed until 8-2-62. Units were processed through final seal by Process Development line and classified by Production. Results were as shown below.

1st Run Signal Corp. Plating Project

	Standard Plating	Duplex Plating
Run Number	592-A	592-B
No. Units Per Run	150	150
Type	P.N.P. dice - Split lot of 300	
Die Attach	Good	Good
Lead Bond	Good	Good
Lead Weld	Good	Good
% Yield at Classification	89.5	86.7
Vce Sat (Fall out)	0	0
Isw (150°) Prod. Equip. (Fall out)	2.4%	0.85%
Isw (150°) Read out on Scope (Fall out)	2.4%	5.99%
Solderability	Fair to Good	Fair

Test units shall be returned to P. Rollason for retaining until completion of Project.

J. S. Horton
Packaging Evaluation

TASK 3 - EXHIBIT 6

FAIRCHILD SEMICONDUCTOR CORPORATION Rec. Report #_____

PACKAGE EVALUATION LOG SHEET QA Rec. Rej. Rep. #_____

Process Development

SIGNAL CORP Date 8-28-62

Operator Evans

Type of Test Preliminary Evaluation

Purpose To evaluate Au Plating and check hermetic seal.

Vendor Fsc Rec. Date 8-28-62 Type Component TO-5 Lot_____

Drawing No FSC-40176 No. Units 3,000 Material Kovar

Package Description TO-5 HDR. Standard Plating - Test #2

PROCEDURE

1. Die Attach 10 Units with Reject Dice.
2. Age 10 Units for 60 Hrs. in N_2 at 300°C.
3. Temp Shock 20 Units at 390°C - 400°C for 20 Sec.
4. Final seal 20 Units in the He and VEECO Check.
5. Check Physical Dimensions.
6. Etch Test for 40 Sec. in CP-8.
7. Check Lead Solderability.
8. Insulation Resistance at 10^{-10} Test Voltage of 250 V. DC.

MACHINE SETTINGS

RESULTS OR CONCLUSIONS

1. Die Attached 10 units - Preform Wet Out Good.
2. Aged 10 Units - No Discoloration - Good Dice Adhesion.
3. Temp Shocked 20 Units - No Discoloration.
4. Sealed 20 Units - No Leakers at VEECO.
5. Physical Dimensions - Within Spec.
6. Etch Test - Good.
7. Lead Solderability - Fair.
8. Insulation Resistance - Within Spec.

MISC. INFORMATION

1. These Units for test #SC2A.

DISPOSITION OF COMPONENTS

1. Units OK for Production.

See other side for additional comments.

TASK 3 - EXHIBIT 7

FAIRCHILD SEMICONDUCTOR CORPORATION Rec. Report #_____

PACKAGE EVALUATION LOG SHEET QA Rec. Rej. Rep.#_____

Process Development

SIGNAL CORP Date 8-28-62

Operator Evans

Type of Test Preliminary Evaluation

Purpose To Evaluate Au Plating and Check Hermetic Seal.

Vendor Fsc Rec. Date 8-28-62 Type Component TO-5 Lot_____

Drawing No FSC-40176 No. Units 3,000 Material Kovar

Package Description TO-5 Standard HDR. - Duplex Plating - Test #2

PROCEDURE

1. Die Attach 10 Units with Reject Dice.
2. Age 10 Units for 60 Hrs. in N_2 at 300°C.
3. Temp Shock 20 Units at 390°C - 400°C for 20 Sec.
4. Final Seal 20 Units in He and VEECO Check.
5. Check Physical Dimensions.
6. Etch Test for 40 Sec. in CP-8.
7. Check Lead Solderability.
   Insulation Resistance at 10^{-10} Test Voltage of 250 V. DC.

MACHINE SETTINGS

RESULTS OR CONCLUSIONS

1. Die Attached 10 Units - Preforms Wet Out Good.
2. Aged 10 Units - Some Discoloration - Good Dice Adhesion.
3. Temp Shocked 20 Units - No Discoloration.
4. Sealed 20 Units - No Leakers at VEECO.
5. Physical Dimensions - Within Spec.
6. Etch Test - Good.
7. Lead Solderability - Fair.
8. Insulation Resistance - Within Spec.

MISC. INFORMATION

1. These Units for SC2B.

DISPOSITION OF COMPONENTS

1. Units OK For Production.

See other side for additional comments.

TASK 3 - EXHIBIT 8

FAIRCHILD SEMICONDUCTOR CORPORATION

Special Test
No. SC-2-A

Originator Peter Rollason Date 9/17/62

Approved [signature] Date 9/17/62 Approved _____ Date _____
(Originator's Dept) (Product Manager)

FT-TYPE TA 4500 Unit Identification _____
(Run No., etc)

Starting Date _____ Originator _____
(Initials)

Die Sort Target Date _____

Prod. Mgr. _____
(Initials)

Classification Target Date _____

Contact originator as indicated on attached Routing Check-off List. Do not hold material at any point not checked.

PURPOSE OF THIS TEST: To evaluate standard Fairchild plating for Signal Corps contract.

INSTRUCTIONS: (Be specific - Attach separate Flow Chart, if necessary)

Die attach 150 standard plated headers (Sample A)

1. Use 4500 dice (see below) normal process through classification.
2. Maintain header batch identity.
3. Save all rejects as indicated below.
   a. die attach
   b. lead weld.
   c. classification
4. Use charge # 11-90-10-00-00 for labor expended on the test.

CONCLUSIONS & RECOMMENDATIONS: (Attach separate report, if necessary)

Dice used on the standard and special plating lots (samples A and B) must originate from the same dice lot.

Originator to recap desired information (emitter diffusion results, die sort results, DA, LB, IW results, etc) on reverse side.

TASK 3 - EXHIBIT 9

FAIRCHILD SEMICONDUCTOR CORPORATION

Special Test

No. SC-2-B

Originator Peter Rollason Date

Approved Peter Rollason Date 9/17/62 Approved Date

(Originator's Dept) (Product Manager)

FT-TYPE TA 4500 Unit Identification (Run No., etc)

Starting Date

Die Sort Target Date

Classification Target Date

Originator (Initials)

Prod. Mgr. (Initials)

Contact originator as indicated on attached Routing Check-off List. Do not hold material at any point not checked.

PURPOSE OF THIS TEST:

To evaluate special plating for Signal Corps contract.

INSTRUCTIONS: (Be specific - Attach separate Flow Chart, if necessary)

Die attach 150 special plated headers (Sample B)

1. Use 4500 dice (see below) normal process through classification.
2. Maintain header batch identity
3. Save all rejects as indicated below
   a. die attach
   b. lead weld
   c. classification
4. Use charge # 11-90-10-00-00 for labor expended on this test.

CONCLUSIONS & RECOMMENDATIONS: (Attach separate report, if necessary)

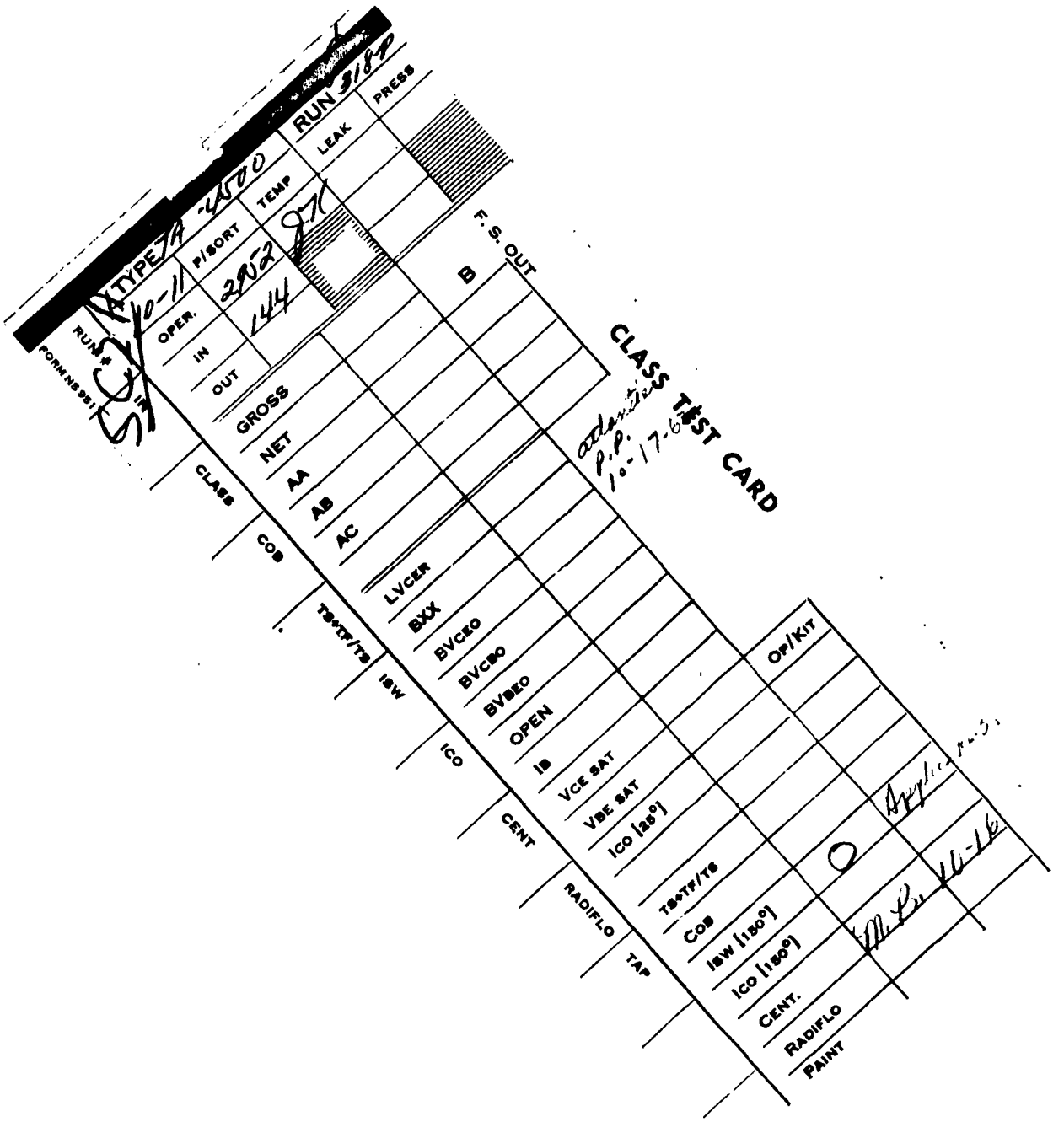
Dice used on standard and special plating lots (samples A and B) must originate from the same dice lot.

Originator to recap desired information (emitter diffusion results, die sort results, DA, LB, LW results, etc) on reverse side.

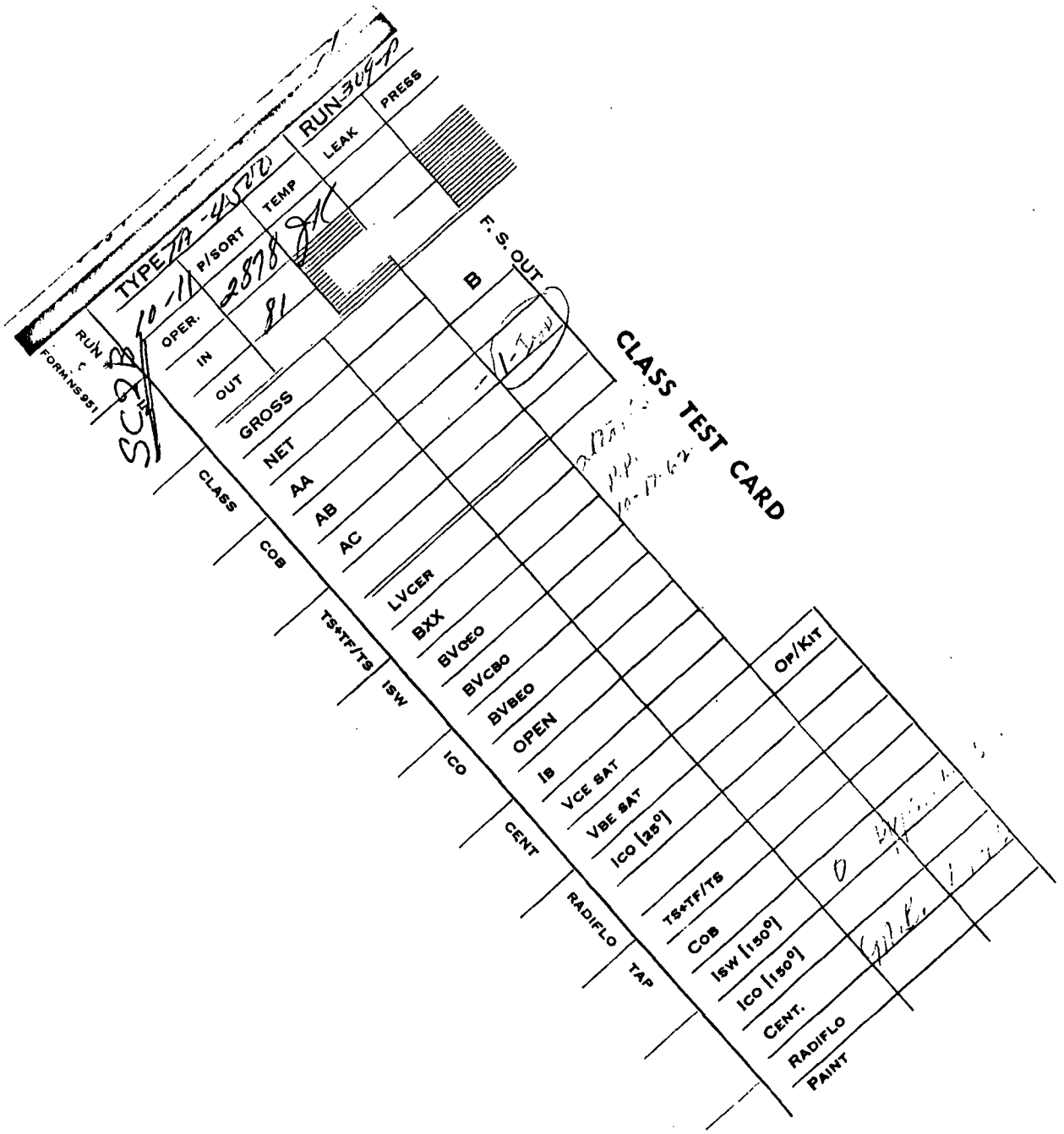
NS734
Rev. 4/11/61

TASK 3 - EXHIBIT 10

PRODUCTION CLASSIFICATION TEST CARD - #SC2A



PRODUCTION CLASSIFICATION TEST CARD - #SC2B



TO: H. Roos

FROM: J. S. Horton

SUBJECT: Tabulation of Results Obtained From Special Test #SC2A and SC2B.

Units evaluated by Packaging Group 8-28-62.

Special test originated 9-17-62.

Special test completed 10-22-62.

2nd Run Signal Corp. Plating Project

	Standard Plating	Duplex Plating
Special Test Number	SC2A	SC2B
Run Number	318P	309P
Dice type	P.N.P. (Split lot)	
Die attach	Good	Good
Lead Weld	Good	Good
Lead Bond	Good	Good
% Yield at classification	87.6	91.3
Vce Sat (Fall out)	1	1
Isw (150°C) Read out on Applications Scope	0	0
Solderability	Fair	Fair

J. S. Horton
Packaging Evaluation

SECTION III

TASK 4 - ISOLATE AND ELIMINATE SOURCES OF GROSS PARTICLES

CONTENTS

SECTION III

TASK 4 - ISOLATE AND ELIMINATE SOURCES OF GROSS PARTICLES

P. M. Weiler

PURPOSE

The purpose of this task is to prevent particles which are detrimental to the operation of a transistor from getting into otherwise good transistors, and to detect particles which do get in transistors. The critical process step in keeping particles out of transistors is the final seal operation. We are attempting to eliminate particles in finished units at this station by: 1. Preventing creation of particles, 2. Keeping existing particles away from uncapped transistors, and 3. Detecting particles in finished units.

PROGRESS

Prevent Creation of Particles.

Weld Schedule - Work finished and report written in last report.

Electrode Finish - During the last quarter, we tried electrodes with ground finishes and found no change in splash. We tried lowering the welder pressure to induce splash and compared the occurence of splash with the ground electrodes with splash occurence of unground electrodes and it was found that there was no significant change in splash, in fact, splash appeared to occur slightly more often with the ground electrodes.

Keep Existing Particles Away From Unwelded Transistors

Lead Guide Cones - The purpose of Lead Guide Cones is to form a shield around the final seal electrode during the actual welding operation. Tool Design has finished a new design of the lead guide cones. However, this new design requires a change in electrode changes forthcoming, it has been decided to postpone testing the new cones several months, until other electrode changes are fixed.

New Plexiglas Dryboxes - The purposes of the new plexiglas drybox are: 1. Prevent any particles outside the drybox from entering into the unfinished transistor area, 2. Provide shielding inside the drybox for uncapped transistors, 3. Provide better visibility of the inside of the drybox and thus give a better indication of cleanliness, 4. Provide an easily cleaned drybox, and 5. Eliminate as far as possible any metal parts in the drybox which might produce metallic particles.

The new plexiglas drybox has been completely designed and has proven successful in the area of cleanliness. The box proves adequate in being air-tight and keeping the uncapped units shielded from any weld splash. The boxes provide a maximum visibility of the inside and lend themselves to cleanliness because of the ability to easily observe the state of cleanliness inside. They have also proved easy to clean because of the good visibility and absence of many "nooks and crannies" where particles could collect. The new boxes also are constructed of almost all non-metallic materials and thus provide very little chance of generating objectionable particles. Exhibits 1 and 2 show the dryboxes which we have been using. They were made from stainless steel with visibility only from the top. The floors were covered with a black tape to prevent the generation of metallic particles from materials sliding over the steel floor, but the tape in turn created "nooks and crannies" for particles to collect. The best tape available was black plastic tape, but this plus the limited visibility restricted the observation of cleanliness. Exhibits 3, 4, and 5 show our new plexiglas drybox, and especially shows the improved visibility of the box. The bottom of the box is made of Phenolic, which is easily cleaned, has a hard surface to prevent particle generation and is a non conductor so that if any particle that might be generated should get into a finished transistor, it would not electrically affect the transistor. All other parts, as far as possible, are made from plastic or nylon to prevent the generation of metallic particles. The box is easily cleaned (most accessory parts shown are easily removed for cleaning) and the cleanliness (or dirtiness) is easily observed.

Thus, we feel that we have a superior drybox which provides excellent visibility, is easily cleaned, and prevents creations of particles.

To date, we have installed a plexiglas drybox on the 2N914 line. The 2N995 line will have the plexiglas drybox installed by the end of February.

Cleaning Procedure - New procedure has been in force on plexiglas dryboxes since about June. The procedure is proving adequate and will be included on new dryboxes as they are installed.

Pre-assembly of Cans - This project appears very promising and we now feel

that this project will prove the best means of keeping particles away from the transistors. Our hope is to develop a jig which will place the cans onto the headers prior to the welding operation.

The procedure will be:

1. Remove transistors in a pre-assembly rack, and cans in a pre-assembly rack from the vacuum bake over into the right hand side of the drybox. (There will be a partition in the middle of the drybox to protect the uncovered transistors from any splash.)
2. Place can rack in the jig in which the cans are inserted and held (open end down) by a vacuum chuck.
3. Place the rack of transistors under the cans which are suspended by the vacuum chuck.
4. Lower the cans onto the transistors. Because the cans and headers are in racks that hold each item in accurate relationship with all other items and with the unit they fit with, this can be done without much trouble. The means of lowering the vacuum chuck with the cans is by an air cylinder. After the cans are assembled on the headers, full pressure is applied to the cylinder and the cans are crimped to the header. However, it is not yet certain that this function can be performed and it will have to be tested. If it cannot be worked, the cans will still be pre-assembled, but the crimping action will not be used.
5. The transistors with the cans pre-assembled on them are passed into the welder section of the drybox for final sealing and will be protected from any splash.

Pre-assembly appears to be an excellent means of preventing gross particles from being sealed in a transistor, because the open cans and uncovered headers are not allowed to be near the welder where they could pick up stray particles. Rather, the headers are capped immediately after entering the drybox, thus keeping down the time which they are uncovered, and the transistors are covered at all times when they are around the welder where there is the danger of weld splash.

To date, we have completed the preliminary design of the jigs and obtained quotes on the equipment necessary. We are now waiting

for fabrication of a prototype jig with which we will test the principle. If it works well we will fix the design and have pre-assembly jigs made for each final seal welder.

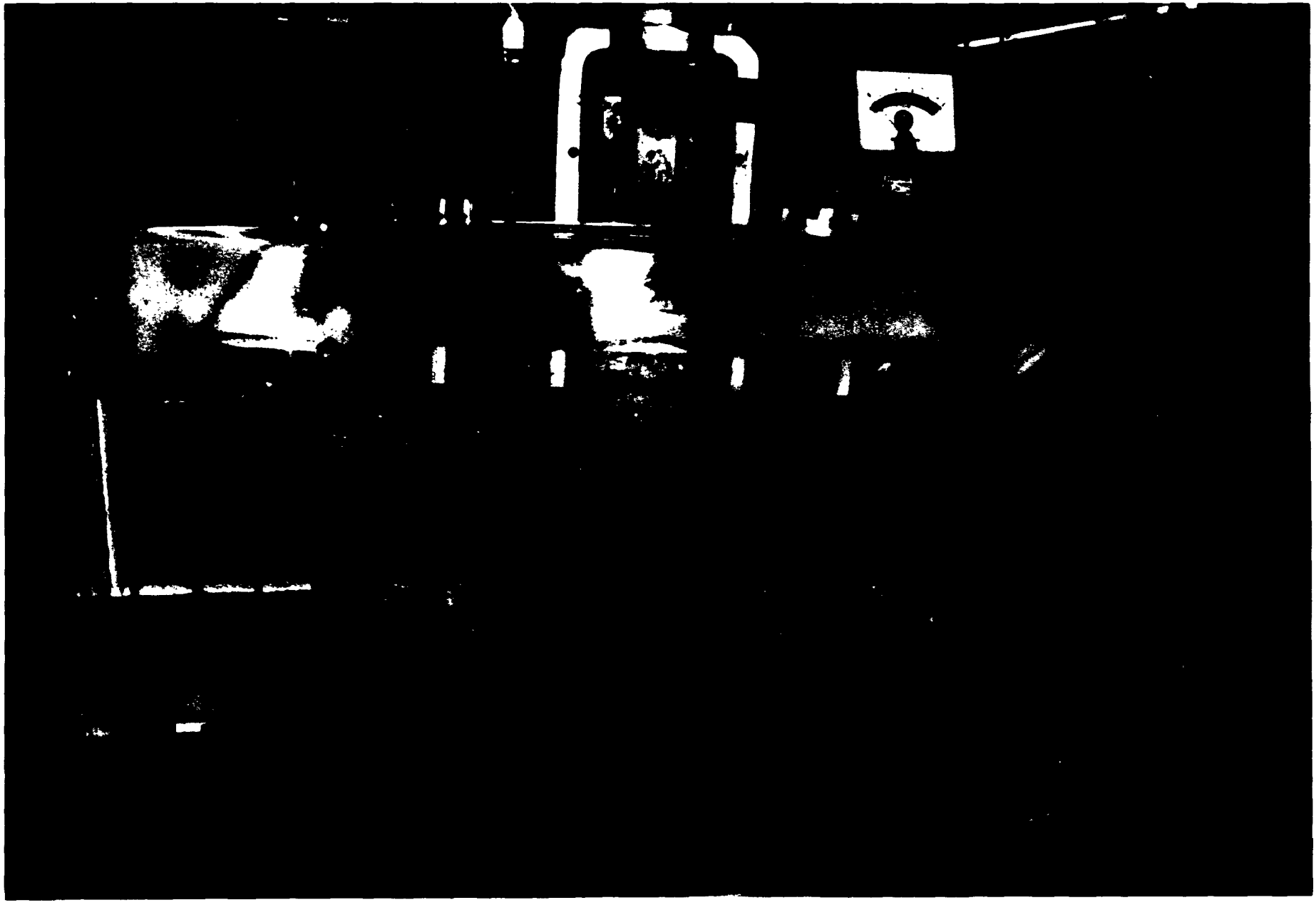
Particle Detection

In an effort to check for the presence of particles in finished transistors, we have been testing a high frequency amplifier. The test will be to shake a transistor in question near the amplifier's microphone. If there is a gross particle inside, it will "rattle" with a high frequency sound, and the amplifier will pick up the sound and amplify it for an operator to hear.

In test of the equipment it has been found to work well with large particles such as loose dice, preforms, and chunks of metal down to about 1/64" diameter. These particles produce a distinct sound in the amplifier. Particles smaller than this are questionable at this time and require more testing.

A jig was fabricated for testing transistors with the amplifier, but the jig produced so much background noise that it was undesirable and is back for redesign. There are also new ideas for the jig which will be tried as they are fabricated. The amplifier appears to work well for large particles and was able to clearly pick out at least one transistor with a particle in a 250 unit batch. We believe it will work well and are now waiting for the new jigs in order to test in large volumes.

TASK 4 - EXHIBIT 4



SECTION III

TASK 5 - PREFORM ELIMINATION

CONTENTS

SECTION III

TASK 5 - PREFORM ELIMINATION

G. E. Davis

ABSTRACT

Vacuum evaporation of preform material onto the backsides of 2N914 and 2N995 devices is proving to be an effective assembly method.

NARRATIVE AND DATA

During the time period covered by the previous quarterly report, doped gold preform material was vacuum evaporated onto the backsides of 2N914 and 2N995 devices. In the case of the NPN device, 2N914, the preform material contained 99.7 percent gold and 0.3 percent antimony. The p-type material used on 2N995 devices was 99.3 percent gold and 0.7 percent boron. A description of the procedure and equipment used to perform the evaporation may be found in the Task 5 section of the previous quarterly report.

At the time of the writing of the previous report the assembly of 2N995 devices was incomplete. Assembly and classification of these units are now complete. Classification data show that 73.5 percent of the units classified were good units. There were no V_{ce} (sat.) or V_{be}(sat.) failures.

Further data on 2N995 devices are available, but haven't been analyzed as yet; therefore V_{ce} (sat.) is the most important parameter to consider in a preform elimination test, since it is an indicator of the contact resistance between the die and the header. V_{be} (sat.) is also considered because it is an indicator of the lead bond quality. Lead bond quality could be affected by the elimination of the separate preform in the assembly of devices. For these reasons, only these two parameters and the switching current, I_{sw}, will be considered in the evaluation of the devices assembled without separate preforms. No I_{sw} data is available at this time.

The 2N914 devices assembled during the period of the previous quarterly report are now being placed in the test program described in that report. Zero hour data are available and frequency distribution charts of this data may be found in Exhibit 3. Three separate frequency distributions for each parameter were constructed, one for each of the test phases. Superimposed on each distribution is the distribution of a control group. The units in the control groups were drawn from finished inventory; these units were assembled using the normal preform assembly procedure.

Inspection of the distributions of V_{be} (sat.) and low current V_{ce} (sat.) will show that there is no significant difference between the test groups and the control groups. Similar inspection of the distributions of high current V_{ce} (sat.), however, will show that the test group is significantly better than the control group. In general, high current V_{ce} (sat.) is lower and the distribution tighter for the test units than for the control units.

CONCLUSIONS

Data obtained to date have shown that vacuum evaporation of preform material is an effective method of eliminating the necessity for the use of separate preforms in the assembly of 2N914 and 2N995 devices. In the case of high current V_{ce} (sat.), the units assembled without separate preforms are superior to those assembled in the normal manner.

PROGRAM FOR NEXT INTERVAL

During the next interval all units, both test and control, shall be subjected to the testing program described in the previous report. Data should be recorded and analysed after 250 hours, 500 hours and 1000 hours of testing. Zero hour data for 2N995 devices shall also be analysed. Any units which fail during the test shall be withdrawn from the test and the failure mode identified and investigated.

TASK 5 - EXHIBIT 1

EQUIPMENT

1. Classification Equipment (2N995): Type 4 Transistor Tester, fabricated by Instrumentation Department, Fairchild Semiconductor.
2. Life Test Parameter Test Equipment: Fairchild Datalogger, fabricated by Instrumentation Department, Fairchild Semiconductor.

TASK 5 - EXHIBIT 2

ELECTRICAL TEST CONDITIONS

1. 2N914
   a. V_{be} (sat.): I_c = 10 ma, I_b = 1 ma
   b. V_{ce} (sat.):
      1) I_c = 10 ma, I_b = 1 ma
      2) I_c =200 ma, I_b =20 ma

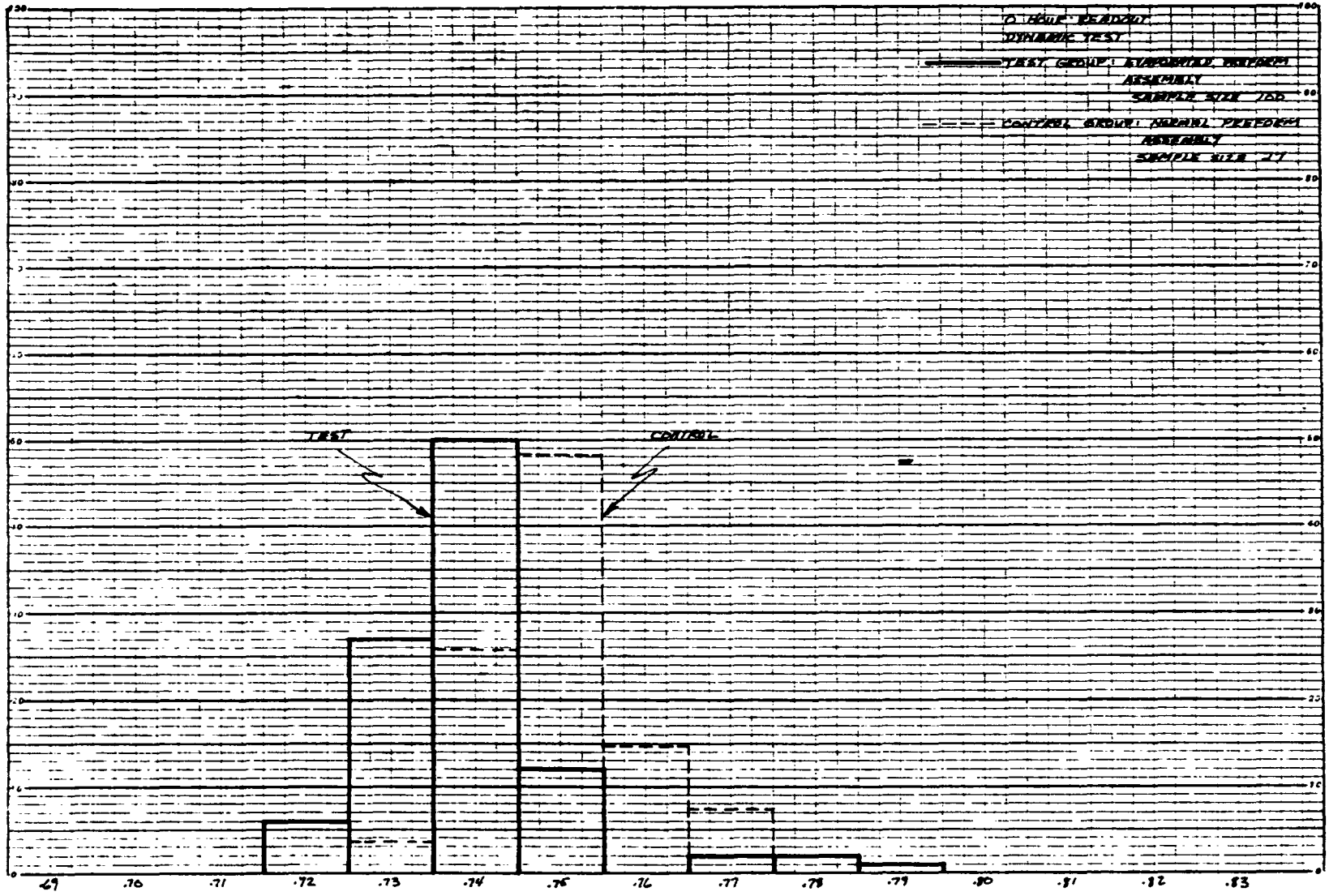
FREQUENCY DISTRIBUTION

V_{BE} (SAT.)

SIGNAL CORPS
DEVICE TB 1341 (2N914)

PREFORM ELIMINATION

I_C = 10ma, I_B = 1ma



V_{BE} (SAT), VOLTS

11/19/62 GED

TASK 5 - EXHIBIT 3

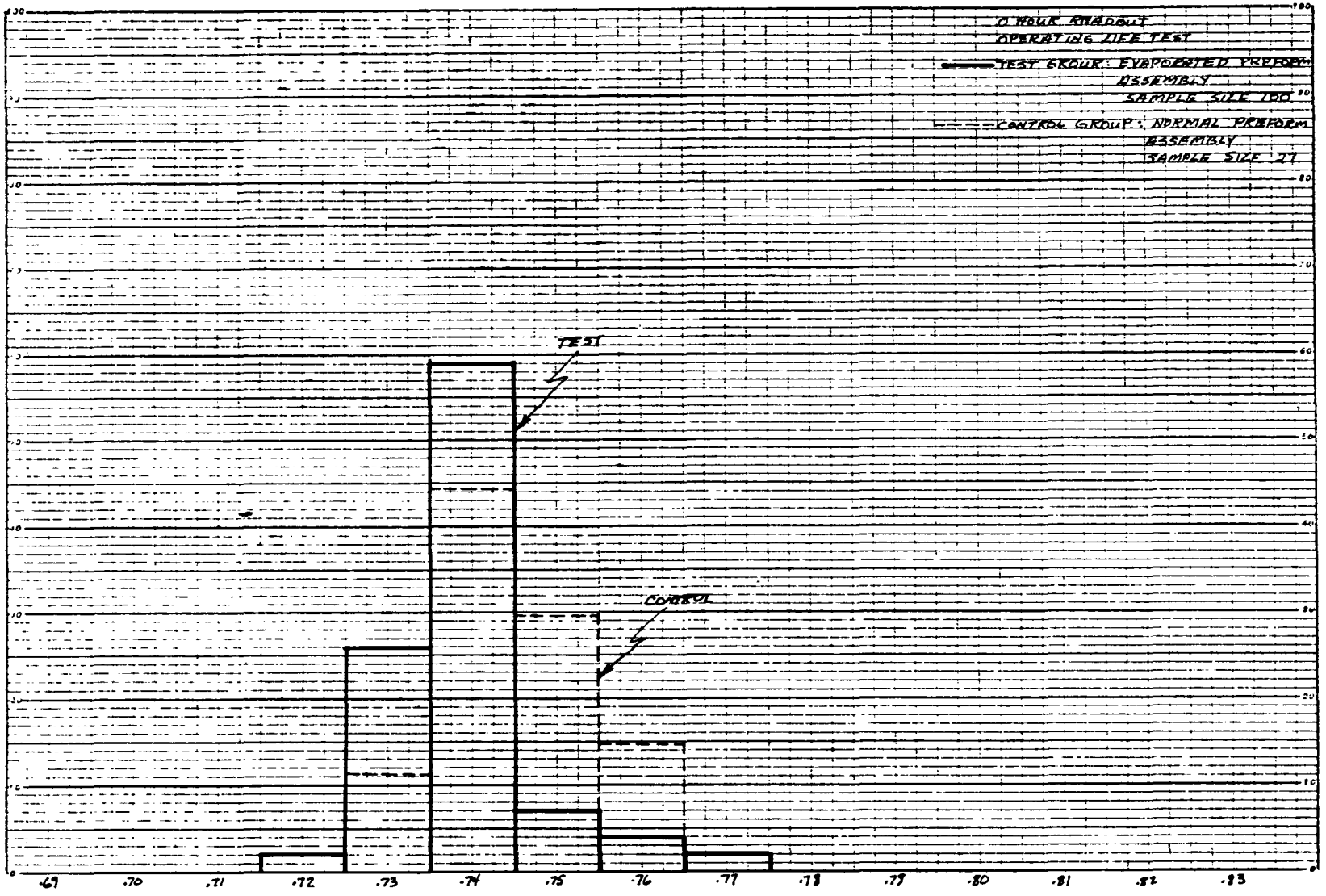
FREQUENCY DISTRIBUTION

V_{BE} (SAT.)

SIGNAL CORPS
DEVICE TB 1341 (2N914)

PREFORM ELIMINATION

I_C = 10 ma, I_B = 1 ma



V_{BE} (SAT), VOLTS

11/9/62 GED

TASK 5 - EXHIBIT 3

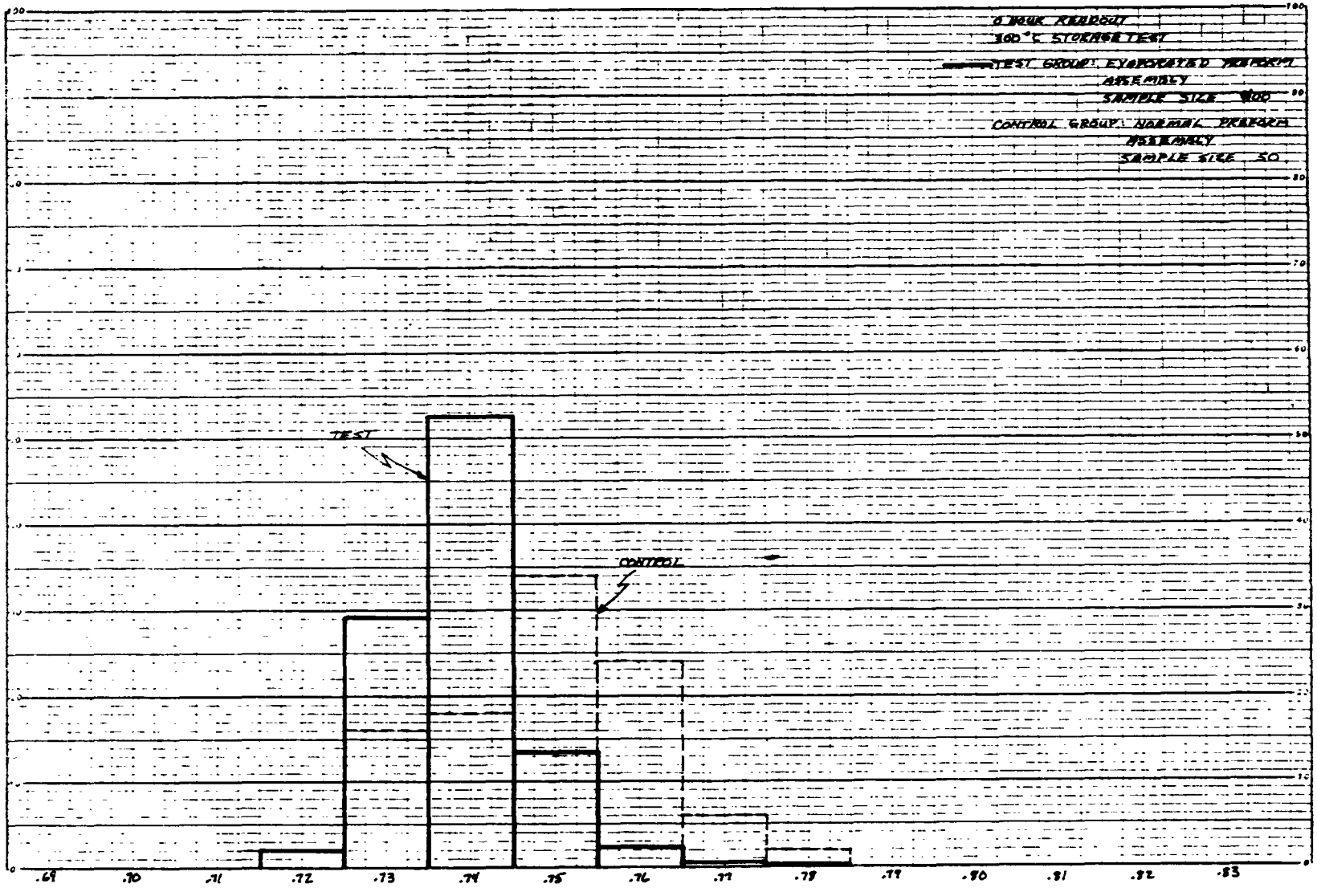
FREQUENCY DISTRIBUTION

V_{BE} (SAT.)

SIGNAL CORPS
DEVICE TB1341 (2N914)

PREFORM ELIMINATION

I_C = 10 ma, I_B = 1 ma



PERCENT

V_{BE} (SAT), VOLTS

11/19/62 GED

TASK 5 - EXHIBIT 3

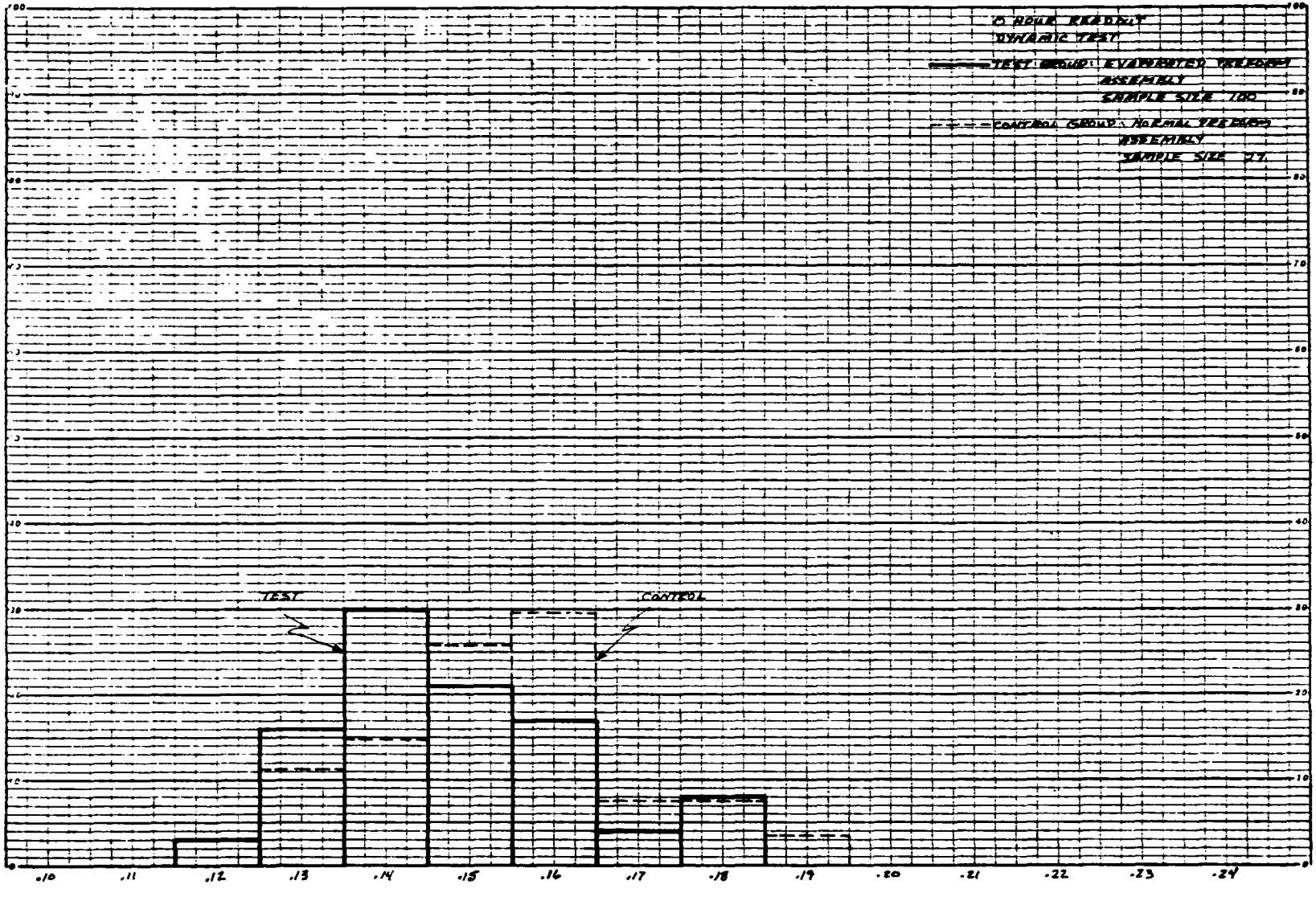
FREQUENCY DISTRIBUTION

V_{CE} (SAT.)

SIGNAL CORPS
DEVICE TIS 134 (2N914)

PREFORM ELIMINATION

I_C = 10 ma, I_B = 1 ma



V_{CE} (SAT), VOLTS

TASK 5 – EXHIBIT 3

11/9/62 GED

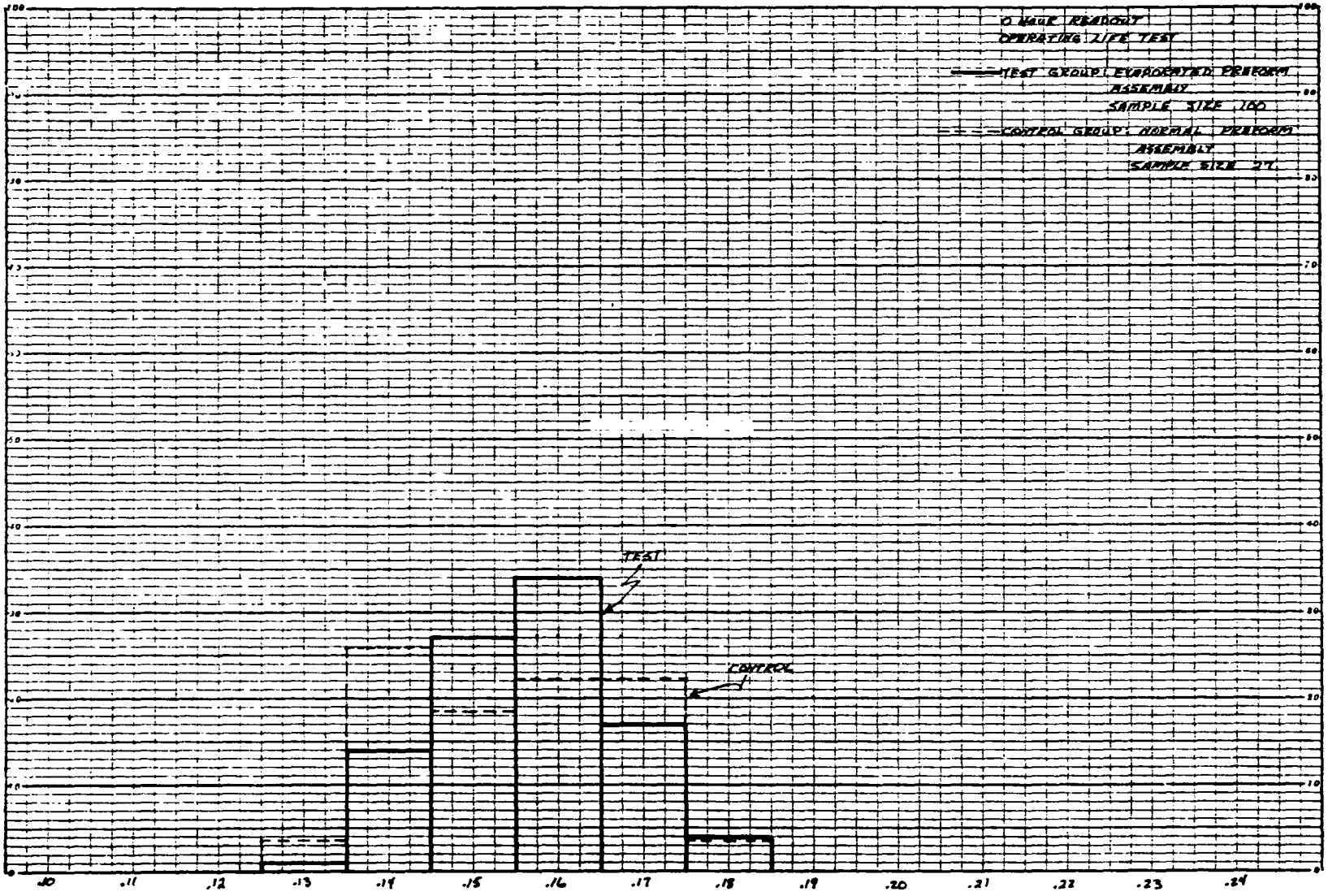
FREQUENCY DISTRIBUTION

V_{CE} (SAT.)

SIGNAL CORPS
DEVICE TIS 1341 (2N914)

PREFORM ELIMINATION

I_C = 10 ma, I_B = 1 ma



PERCENT

V_{CE} (SAT), VOLTS

TASK 5 - EXHIBIT 3

11/19/62 GSD

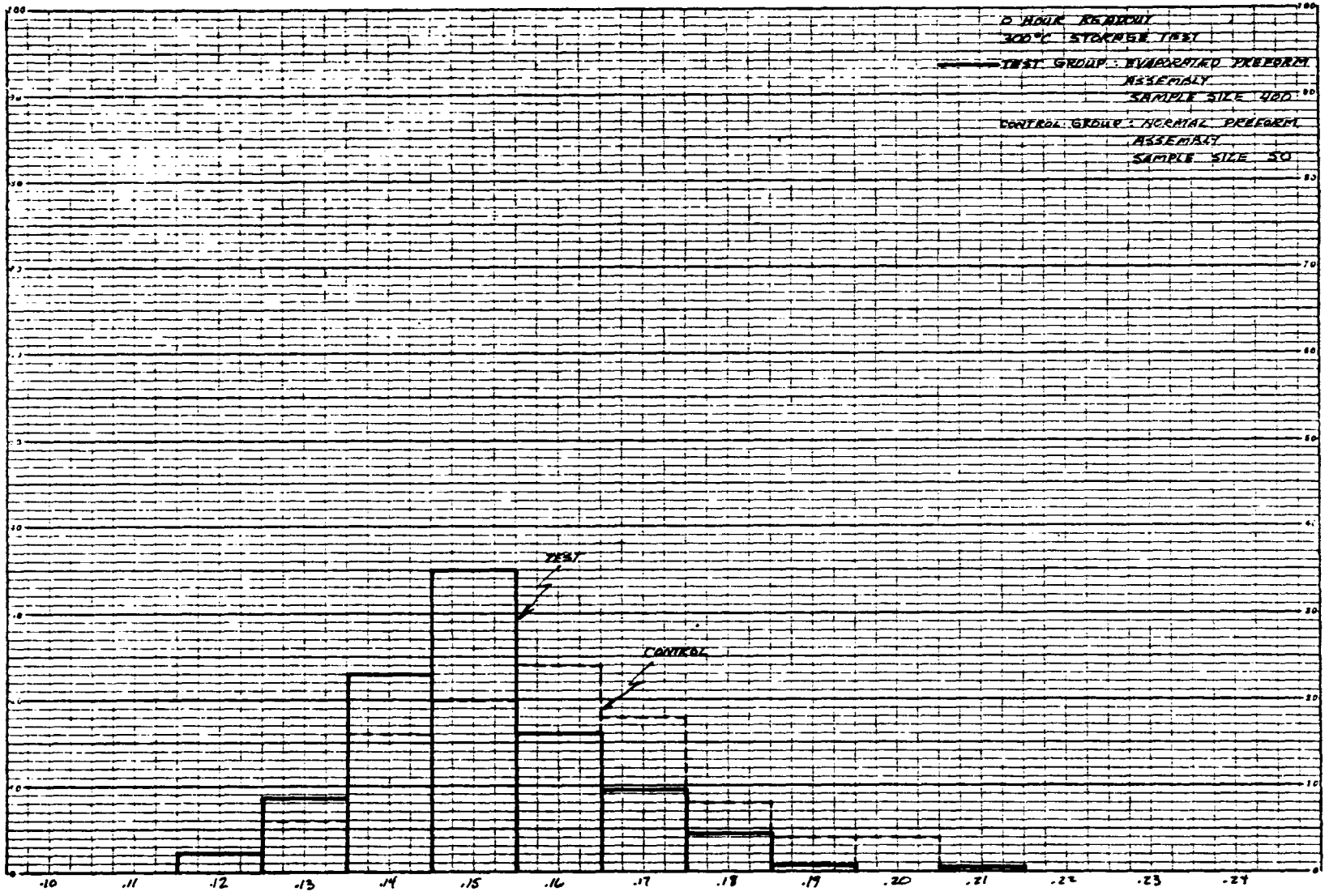
FREQUENCY DISTRIBUTION

V_{CE} (SAT.)

SIGNAL CORPS
DEVICE TB 1341 (2N914)

PREFORM ELIMINATION

I_C = 10ma, I_B = 1ma



PERCENT

V_{CE} (SAT), VOLTS

TASK 5 - EXHIBIT 3

11/19/62 GSD

FREQUENCY DISTRIBUTION

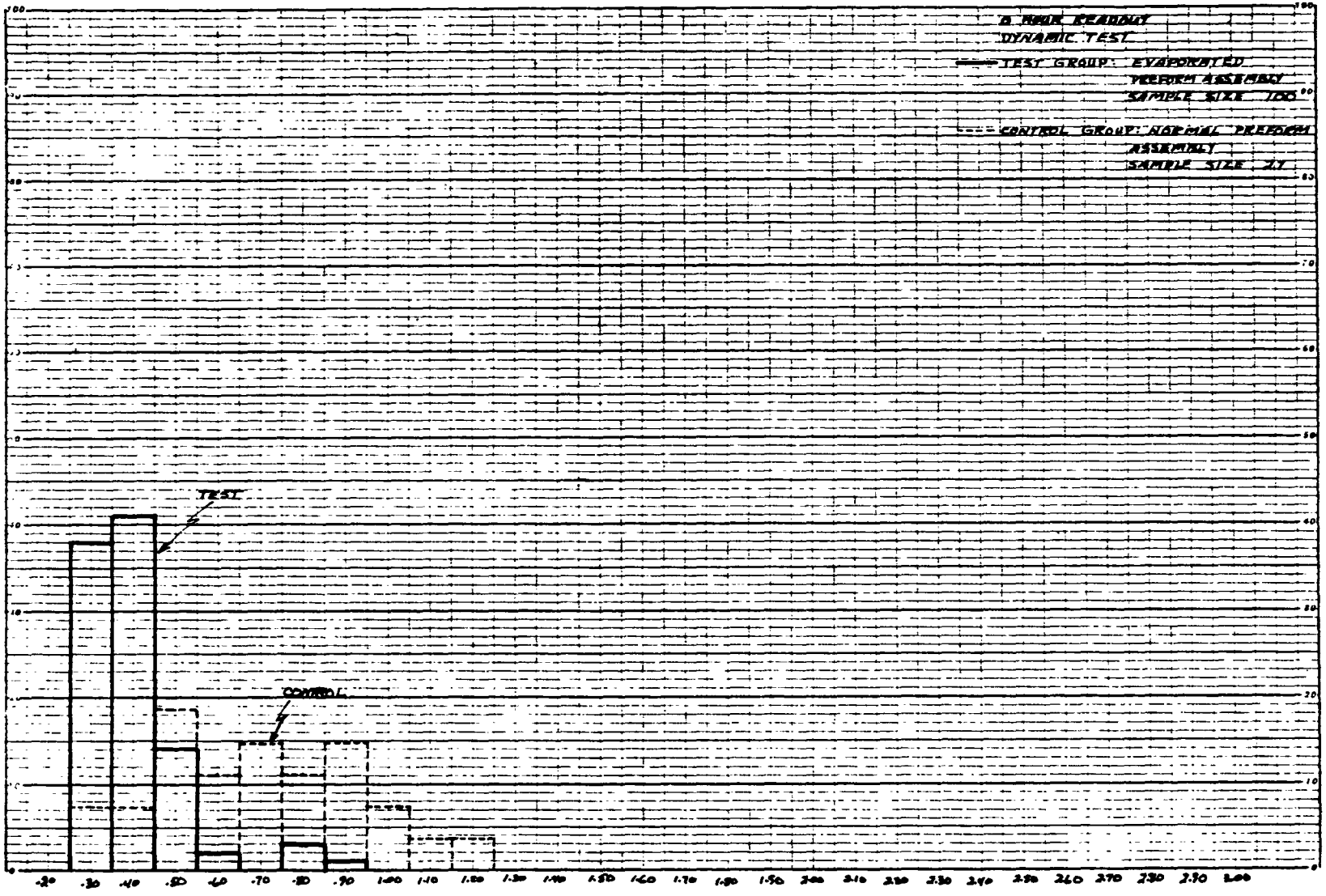
V_{CE} (SAT.)

SIGNAL CORPS

DEVICE TB 1341 (2N914)

PREFORM ELIMINATION

I_C = 200 ma, I_B = 20 ma



V_{CE} (SAT), VOLTS

TASK 5 - EXHIBIT 3

11/19/62 G&D

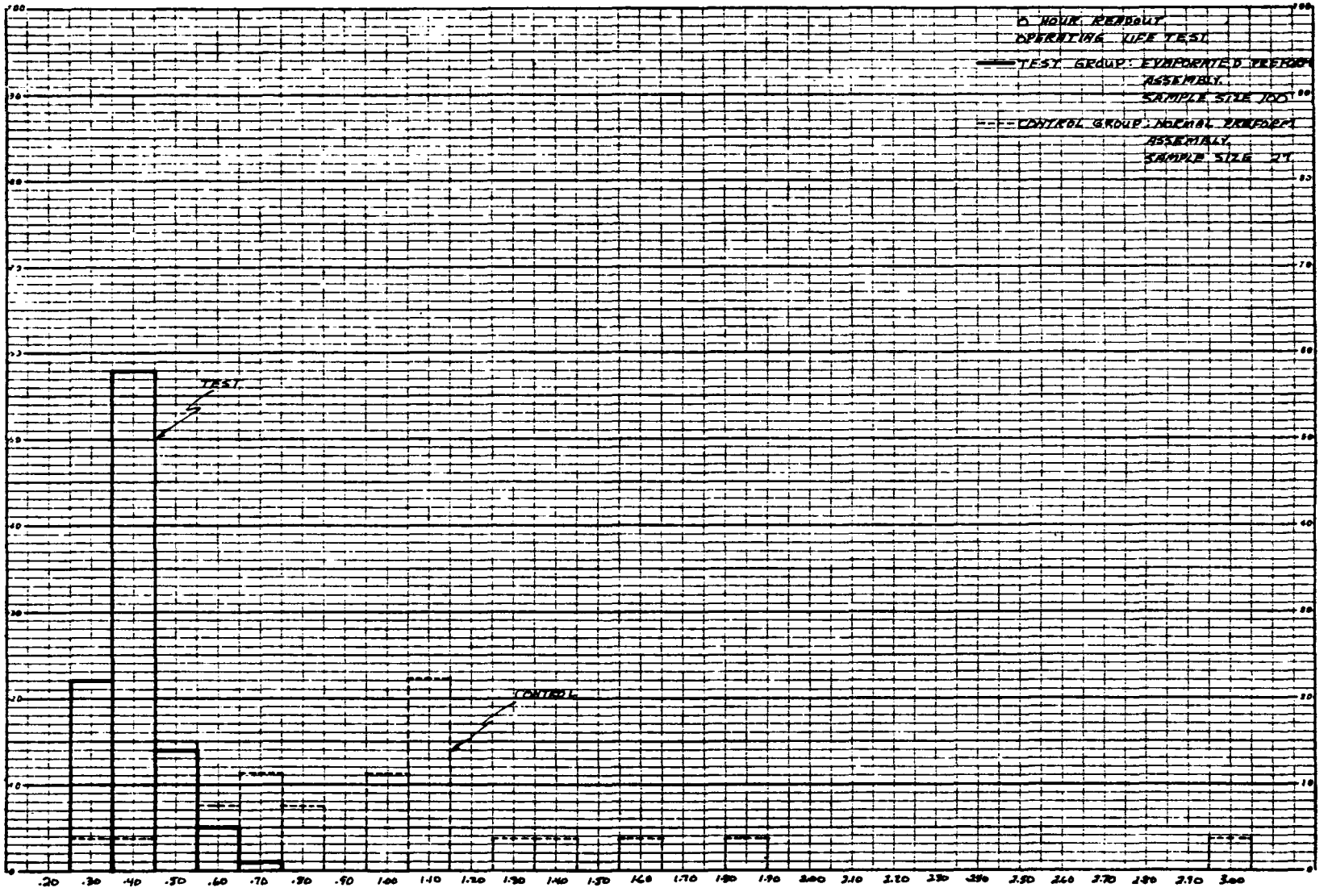
FREQUENCY DISTRIBUTION

V_{CE} (SAT.)

SIGNAL CORPS
DEVICE TB/341 (2N514)

PREFORM ELIMINATION

I_C = 300 ma, I_B = 30 ma



V_{CE} (SAT), VOLTS

TASK 5 - EXHIBIT 3

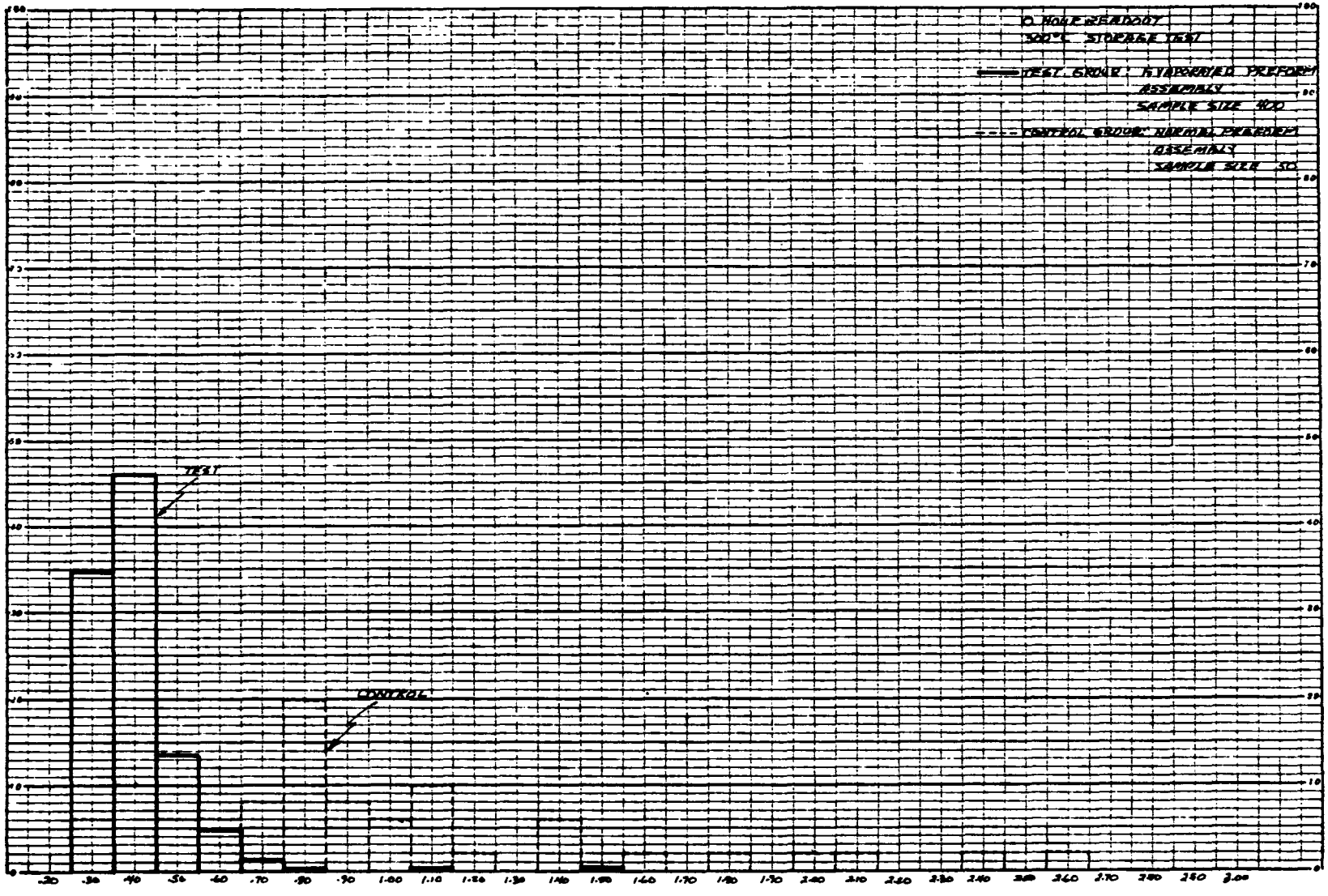
FREQUENCY DISTRIBUTION

V_{CE} (SAT.)

SIGNAL CORPS
DEVICE TIS 1341 (2N514)

PREFORM ELIMINATION

I_C = 200ma, I_B = 20ma



V_{CE} (SAT), VOLTS

TASK 5 - EXHIBIT 3

SECTION IV

CONFERENCES

On October 18, 1962 a conference was held in Mountain View, California between representatives of the Army Electronic Materiel Agency and Fairchild Semiconductor personnel. At the meeting the objectives, progress, and plans for this contract were reviewed. Equipment and processes being improved under terms of this contract were examined by the U.S.A.E.M.A. representatives.

SECTION V

IDENTIFICATION OF TECHNICIANS

In August, September and October of 1962, 4608.5 hours were expended by Fairchild engineering and support personnel on this contract, exclusive of technical supervision whose time is accumulated in overhead accounts. Following is a list of key technical personnel and time expended by them.

SUMMARY OF HOURS CHARGED BY KEY TECHNICAL PERSONNEL

	Hours
Arnold, S.	13.0
Butts, W.	177.5
Carmichael, E.	60.0
Corzine, J.	221.5
Davis, G.	33.0
Fitch, W.	8.0
Gregory, A.	76.0
Hammer, R.	258.5
Horton, J.	10.0
Kobrin, D.	186.0
Levitsky, M	33.0
Martin, D.	126.0
Murphy, J.	292.0
Myers, D.	32.0
Rollason, P.	61.0
Schroeder, J.	204.0
Sentous, J.	104.0
Shea, D.	52.0
Simionato, J.	16.0
Tsang, W.	1.0
Vaatveit, E.	12.0
Warren, W.	397.0
Weiler, P.	100.0